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LABORATORY EVALUATION OF AUSTRALIAN RATION PACKS

AR-008-206

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Abstract

The results of studies of the storage stability of ascorbic acid, thiamine, riboflavin and niacin in fortified ration pack components are reported. Fortification of selected ration components with ascorbic acid and thiamine was found to be necessary but fortification with riboflavin and niacin was found to be unnecessary. Additional carriers for fortification with ascorbic acid and thiamine need to be identified. Conditions in most Australian Defence Force warehouses lead to rapid depletion of ascorbic acid and thiamine. The results of analysis of the 1986 and 1987 procurement of rations are reported and discussed, including a nutritional assessment of the Individual Meal Combat Ration (IMCR) and the revised Combat Ration One Man (CR1M). Some nutrient levels in the IMCR were found to be inadequate. The energy level of the CR1M was found to be deficient for typical users due to lower fat levels in the revised ration packs. The CR1M was found to be deficient in copper. Adequate levels of ascorbic acid and thiamine in CR1M at the time of consumption are dependent on adequate fortification. The assessment of compliance with salt specifications stated in terms of added salt was found to be almost impossible. Some deficiencies in the rations are related to failure of some components to meet specifications.

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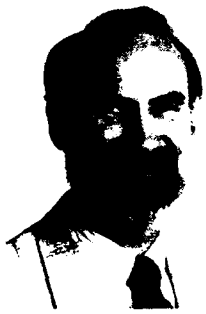
G.F. Thomson



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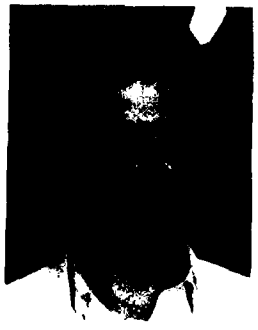

M.J. Lichon

Michael J. Lichon, B.Sc(Hons) was employed as a professional officer in food science. He was engaged in research to evaluate foods for use by ADF personnel, including nutrient composition. He is now undertaking a doctoral research project in environmental science at the University of Tasmania.

Contents

Laboratory Evaluation of Australian Ration Packs

1. Introduction

Previous reports (James, Lichon, Tattersall, Thomson & Hancock, 1988 for last in series) have detailed the results of analyses of ration packs from preceding packaging programs. This report discusses the results obtained by analysis of the 1986 and 1987 packaging programs and reports the results of storage stability studies of ascorbic acid, thiamine, riboflavin and niacin in selected fortified ration components.

A sample of each ration component was analysed for moisture, fat, protein, ascorbic acid (vitamin C), thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), and salt if a specification existed. All components of the Individual Meal Combat ration (IMCR) 1986 procurement and the revised Combat Ration One Man (CR1M) 1987 procurement were analysed irrespective of the existence of a specification, allowing nutritional assessment. CR1M was revised with new menus based on the recommendations of Forbes-Ewan and Waters (1986). Values for carbohydrate were estimated from the carbon contents after adjusting for fat and protein. Energy values in kilojoules (kilocalorie = 4.186 kilojoules) were calculated from the values recommended by Thomas & Corden (1977). The rations prepared at Materials Research Laboratory - Tasmania (MRL-Tasmania) were examined for microbiological quality.

These evaluations are based on the nutritional requirements stated in the Army Staff Requirement, No.69.1, Operational Rations (Director of Logistic Development, 1983). These requirements are interpreted to be those of the average Australian soldier, who is approximately 75 kg. His requirements for various grades of activity are listed in Table 1, as suggested by the National Health and Medical Research Council (1987) and recently revised (Truswell, 1989). Recent studies (Morrissey, Forbes-Ewan, Waters and Gregg, 1989; Morrissey, Cavanough, Forbes-Ewan and Waters, 1990) have shown that the energy expenditure of Australian soldiers engaged in typical military activities range from 14,000 kJ to 20,600 kJ, with 16,000 kJ being a typical expenditure. This level of activity is therefore equivalent to a grade 3 level of activity in Table 1, rather than grade 2 used in earlier evaluations (James *et al.*, 1988).

Table 1: Nutrient requirements of 25 year old, 75 kg man per day

NUTRIENT	REQUIREMENT			
	GRADE 0	GRADE 1	GRADE 2	GRADE 3
Energy kJ	9,000	12,200	13,800	16,000
Protein g (minimum)	70	70	70	70
Protein 12% energy g	-	86	97	113
Ascorbic acid (Vit C) mg	40	40	40	40
Niacin(Vit B2) mg	14.4	19.5	22.0	25.6
Thiamine (Vit B1) mg	1.1	1.2	1.4	1.6
Riboflavin (Vit B3) mg	1.1	1.5	1.7	1.9
Sodium g	0.92-2.3	0.92-2.3	0.92-2.3	0.92-2.3
Potassium g	2-5.5	2-5.5	2-5.5	2-5.5
Magnesium mg	320	320	320	320
Phosphorus g	1	1	1	1
Calcium mg	800	800	800	800
Iron mg	7	7	7	7
Zinc mg	12-16	12-16	12-16	12-16
Copper mg	2-3	2-3	2-3	2-3
Description of Activity	Basal, Maintenance	Normal 8 h light physical work/day, e.g. Clerical	Moderate, e.g. Infantry	Strenuous, e.g. Labouring

Sources; NH & MRC, 1987, Truswell, 1989, Whitney and Hamilton, 1984.

Recent evaluations (James and Forbes-Ewan, 1981; James, Forbes-Ewan and Thomson, 1982; James, Tattersall, Forbes-Ewan, Hancock and Thomson, 1984; James, Lichon, Tattersall, Thomson and Hancock, 1986) have noted many cases where fortified ration components do not meet the vitamin specifications (DPI, 1984/8). In some cases the components passed specification for vitamin content when tested at procurement (Australian Government Analytical Laboratories, personal communications, 1981-1988), or were obtained from reliable manufacturers, which suggests that many of these components may have met specifications (DPI, 1984/8) at procurement. This leads to concern that some of the vitamins may have poor storage properties in the components selected as carriers.

All combat ration packs are required to have a shelf life of at least twelve months in temperate areas and six months in tropical areas (DLD, 1983). In addition there have been demands on cost grounds to extend the life of the rations to two or three years. Recent observations by field observers from this establishment (Forbes-Ewan, Personal Communication, 1987) show that rations are being held in storage for at least two years. The normal procurement cycle means that components are acquired over a period of several months and then packaged in the ultimate ration pack over a period of a year. Thus, the individual components must have a shelf life of at least two years, and preferably three to four years.

The vitamins of greatest concern have been ascorbic acid and thiamine due to their well documented poor storage stability (Kramer, 1982; Priestley, 1979). Riboflavin is very susceptible to degradation by light, however, in rations it is

normally well protected by the packaging. There is some loss of riboflavin due to heating of some foods (Heidelbaugh and Karel, 1982). Niacin is generally regarded to be stable under most conditions of storage.

Vitamin degradation can generally be modelled as a first order reaction (Glasstone & Lewis, 1963; Priestley, 1979), when the vitamin is the rate limiting factor, with the general equation :

$$x = ae^{-Ate^{-E/RT}} \quad (1)$$

where x is concentration at time t and temperature T; a is initial concentration; A is a reaction rate constant; E is the activation energy for the reaction; and R is the gas constant (8.314 J $mol^{-1}K^{-1}$). This becomes a linear expression using the natural logarithmic transform :

$$\log_e(\log_e(a/x)) = \log_e(t) + \log_e(A) - E/RT \quad (2)$$

If the equation is modelling degradation then the exponential term must be negative, ie A is negative. This form of the logarithmic transform ensures A is positive and that $\log_e(A)$ will be real. When the vitamin is unstable in the system then A will be very large. As the vitamin becomes more stable then A will become closer to zero. The values will be affected by a variety of factors within each system.

If the vitamin is not the rate limiting factor and the rate limiting factor, such as a catalyst, is not consumed in the reaction then the vitamin degradation may be modelled as a zero order reaction with the general equation :

$$x = a - k_t t - k_T T \quad (3)$$

where k_t and k_T are rate constants for time and temperature.

If environmental factors, such as humidity, affect the rate limiting factor, then it can be included as an additional term. The relative humidity (rh) of the environment may be such a term when the nature of the packaging allows the humidity to affect the food material. Thus, relative humidity (rh) may be included in the equation 3 :

$$x = a - k_t t - k_T T - k_h rh \quad (4)$$

Ascorbic acid stability is known to be reduced with increasing temperature and pH, or the presence of oxygen, enzymes or metal catalysts (Tannenbaum, Young and Archer, 1985, p. 488). Its stability is promoted by dissolved salt and sugars, probably through lower oxygen solubility. The concentration of ascorbic acid in solution and the ratio of ascorbic acid to dehydroascorbic acid also have an influence. There is, however, evidence that fructose is a catalyst in the anaerobic degradation of ascorbic acid (Huelin, Coggiola, Sidhu and Kennett, 1971). The temperature, moisture and component selected as carrier are important factors determining ascorbic acid stability. The activation energy (E) in liquid systems is 96.7 kJ mol^{-1} (De Ritter, 1982). Kramer (1982) reports significant (50%) ascorbic acid loss after six months at -20°C in steak & tomato sauce. Canned tomato juice was found to retain 90% ascorbic acid after twelve months at 24°C and tomato flakes retained 90% ascorbic acid after three months at 38°C (Kramer, 1982).

Mixed processed foods are more difficult to model as they are more complex systems.

Thiamine stability is known to be reduced with increasing temperature, pH and water activity, or the presence of sulphite, nitrite or catalytic metals (e.g. copper) (Tannenbaum *et al.*, 1985, p. 495). Its stability is improved by the presence of casein and soluble starch. Temperature and the component selected as carrier are the more important factors. The activation energy (E) in liquid systems is 113 kJ mol^{-1} (De Ritter, 1982). Kramer (1982) reports that there can be significant thiamine loss in steak & tomato sauce at -20°C in three months. However, canned tomato juice retains 90% of thiamine at 23°C for twelve months. In mixed processed foods, the system is even more complex to model and thus, prediction of thiamine stability in a particular food is difficult (Tannenbaum et al., 1985, p. 497).

Aird (1961), Baigent (1965), and Heuston (1972) have undertaken studies of the storage stability of ascorbic acid and thiamine in fortified combat ration components. Their conflicting conclusions are derived from a range of similar ration components. None of these ration component studies used statistical methods for the evaluation of results and depended on single sample determinations at each temperature/time point. James *et al.* (1982) found variations of up to 50% of the mean initial concentration of thiamine and ascorbic acid in fortified items of Emergency Flying Ration (EFR). A storage trial (James *et al.*, 1982) on these components showed that less than 30% of thiamine is retained after two years at 37°C, while ascorbic acid retention ranged from 5% (soup cubes) to 89% in *fruit candy*. Thus, the storage performance of vitamins is very dependent on the food selected as the carrier.

The analytical methods used in the earlier studies were simple rapid methods. The High Pressure Liquid Chromatography (HPLC) method for ascorbic acid (James and Forbes-Ewan, 1984) has been shown to be superior to the dichlorophenol-indophenol method, previously used, with respect to specificity and precision. The HPLC method for thiamine and riboflavin allows for more selective and reliable determination of both vitamins with a single analysis run (James & Hancock, 1989).

This study examines :

* EFR ration chocolate and coffee for the storage stability of ascorbic acid and hiamine.

* EFR fruit candy for the storage stability of ascorbic acid.

* Combat Ration Ten Man (CR10M) fortified soup powders for the storage stability of ascorbic acid, thiamine, riboflavin and niacin.

* CR10M unsweetened condensed milk for the storage stability of ascorbic acid.

* The Individual Meal Combat Ration (IMCR) main meal items for the storage stability of ascorbic acid, thiamine, riboflavin and niacin.

* 1987 procurement of CR1M items for storage stability of ascorbic acid, thiamine, Riboflavin and niacin under normal warehouse conditions.

* Compliance of components procured in 1986 and 1987 with Australian Defence Force Food Specifications (DPI, 1984/8).

* Nutrient composition of 1986 IMCR and the revised CR1M.

2. Materials and Methods

2.1 Warehouse Temperature Measurement

The air temperature was monitored at 9 am and 4 pm daily in warehouses at Townsville, Ashgrove, Liverpool, Puckapunyal, Hobart and Karrakatta, which are used to store combat rations. Townsville warehouse was monitored with a continuous clockwork recorder. The remainder were manually recorded. The data was plotted for the time period January to December using ENABLE OA (The Software Group, 1988) from data gathered over the period 1 December 87 to 30 June 90.

2.2 Storage Studies

2.2.1 1987 Procurement of CR1M

The 1987 procurement of CR1M was analysed after packing and also after storage from packing until 11 August 88 at the Morebank warehouse (Sydney), then Hobart warehouse until transfer to MRL-Tasmania 21 December 88.

2.2.2 Controlled Storage Conditions

Three to ten samples were taken of each component to obtain the initial concentrations of the vitamins of interest. Components of:

* EFR fortified with vitamins, ie *ration chocolate, instant coffee,* and *fruit candy;*

* encapsulated ascorbic acid fortified *ration chocolate* prepared by Cadbury-Schweppes;

* ascorbyl palmitate fortified *ration chocolate* prepared by Cadbury-Schweppes;

* *beef meat balls with bacon & vegetables, beef meat balls with sweet & sour sauce, beef minced with tortellini, chicken & vegetables,* and *lamb & vegetables with rosemary* from the IMCR;

* *beef noodle, chicken noodle, pea & ham,* and *tomato soup* powders, and *unsweetened condensed milk* (canned) from the CR10M;

were placed in storage, at MRL-Tasmania, according to the pattern described in Table 2. Temperature was controlled to within 2°C of the set point. Humidity was not controlled in most chambers, but was estimated from the temperature conditions. The 50% relative humidity (rh) at 48°C was maintained with the aid of water sprays controlled on the basis of wet bulb temperature to within 1% rh.

Table 2: Time of storage in months versus storage conditions

	Temperature, °C / Relative Humidity, %					
Components of	1/99	20/60	30/30	37/25	48/13	48/5
Emergency Flying Ration					3	3
	6			6	6	6
	12		12	12	12	12
	24		24	24		
	60		60	60		
Ration Chocolate		3	3	3		3
	6	6	6	6		6
	12	12	12	12		12
	24	24	24	24		
IMCR						3
	6		6	6		6
	12	12	12	12		12
	24	24	24	24		
	48	48	48	48		
CR10M					3	3
	6		6	6	6	6
	12	12	12	12	12	12
	24	24	24	24		
	48	48	48	48		

2.2.3 *Ration Chocolate*

Cadbury-Schweppes prepared two batches of *ration chocolate* fortified with ascorbic acid encapsulated in ethyl-cellulose beads and a batch fortified with ascorbyl palmitate specifically for the trial. To evaluate the effect of processing on the encapsulated ascorbic acid, the beads were added prior to refining the chocolate paste or at the conching stage after refining. Ascorbyl palmitate was added at the conching stage with flavouring.

2.2.4 *Data Collection and Interpretation*

The various ration components were claimed to be fortified by the manufacturers at the levels shown in Table 3.

The EFR *coffee* and *chocolate* were analysed for moisture, ascorbic acid and thiamine. CR10M *unsweetened condensed milk* and EFR *fruit candy* were analysed for moisture and ascorbic acid. The other components were analysed after the prescribed storage period for moisture, ascorbic acid, thiamine, riboflavin and niacin. Graphical presentation of results was conducted with ENABLE OA (The Software Group, 1988).

Table 3: Specified vitamin fortification levels mg/100 g

Component	Ascorbic Acid	Thiamine	Riboflavin	Niacin
EFR				
Chocolate	22.0	2.2		
Instant coffee	420.0	21.1	21.1	140.0
Fruit candy	106.0			
IMCR				
Main meals	30.0	0.4	0.5	7.0
CR10M				
Soup powders	106.0	5.2	5.2	35.3
Unsweetened condensed milk	66.0			

Statistical analysis of data was undertaken with the aid of NWA Statpak (Northwest Analytical, 1986). Regression analysis of the vitamin storage data was based on the linear double logarithmic form of the first order equation (2), but forcing the coefficient of the $\log_e(t)$ to 1 by including the term $\log_e(t)$ in the dependent variable, that is:

$$\log_e(\log_e(a/x)) - \log_e(t) = \log_e(A) - E/RT \qquad (5)$$

As this expression is undefined if x exceeds a (the initial concentration) the value of a was set to the estimated initial concentration, a value rounded up from the maximum value obtained in a data set. Only this estimated initial concentration would then be undefined and therefore excluded from the analysis. Results below detection limits were treated as missing data in order to avoid excessive bias in the regression analysis. Regression analysis was also undertaken based on the zero order equations 3 and 4.

2.3 *Analytical Methods*

The determination of moisture, protein, carbohydrate, ascorbic acid, niacin, energy and salt were undertaken according to the same procedures as used in previous reports (James & Forbes-Ewan, 1984, James *et al.*, 1988). Fat was determined according to the enzymatic hydrolysis method (Lichon, Tattersall & James, 1987) in all components except dairy products which were determined by a draft revision (SAA, 1986) of the Australian Standard method, AS2300.

Ascorbyl palmitate was determined by HPLC with amperometric detection at 0.6 V according to the method of James & Hancock (1989b).

Early EFR thiamine determinations were made using the thiochrome method (Association of Official Analytical Chemists, 1980, 43.024-43.030). Readings were taken by injecting the iso-butanol extract into a flow injection system using iso-butanol as carrier and a Jasco Fluorometer set at excitation 365 nm and emission 444 nm as detector.

Later thiamine and riboflavin concentrations were determined simultaneously by HPLC with fluorometric detection and post column formation of thiochrome (James & Hancock, 1989b; Wehling and Wetzel (1984).

Chromatographic data was collected and interpreted with electronic integration. Early ascorbic acid results were obtained with the aid of a Sigma 10 Chromatography Data Station (Perkin-Elmer). All other results were obtained with the aid of a Nelson 2600 Chromatography Data System (Nelson Analytical Inc., 1986) on a micro-computer.

Niacin was determined microbiologically (AOAC, 1980, 43.155).

Phosphorus, sodium, potassium, calcium, magnesium, copper, iron, zinc, lead, and cadmium were determined by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES) after digestion with sub-boiling distilled nitric acid (James *et al.*, 1988).

3. *Results and Discussion*

The temperatures in the warehouses were plotted for the sites Townsville (Fig. 1), Ashgrove (Fig. 2), Liverpool (Fig. 3), Puckapunyal (Fig. 4), Hobart (Fig. 5), and Karrakatta (Fig. 6). The initial data gathered during 1988 had many gaps due to failure to rewind the clockwork recording device in Townsville, and due to the collectors receiving an unauthorised instruction to cease collection. The data was supplemented with further collections during 1989/90, which also had gaps. The combined data from 1 December 87 to 30 June 90 profiles temperature conditions in warehouses for most of a year. It is clear that the temperature in the warehouses, except for Puckapunyal and Hobart, exceeds 20°C for at least six months a year.

The storage period of the 1987 procurement of CR1M corresponds with the early period plotted in Figure 3 and the latter period in Figure 5. The total storage period would have included approximately five and a half months at 20°C or higher.

The results for each time – temperature point of the storage trial on each of the components analysed are detailed in Appendix A (on microfiche).

3.1 *Initial Concentrations of Vitamins for Stability Studies*

The initial vitamin concentrations in each component analysed are presented in Table 4. Results of the storage stability of the vitamins, in representative components subjected to the storage trial, are presented as the mean of the set of results for each time – temperature point in Figures 7 to 12.

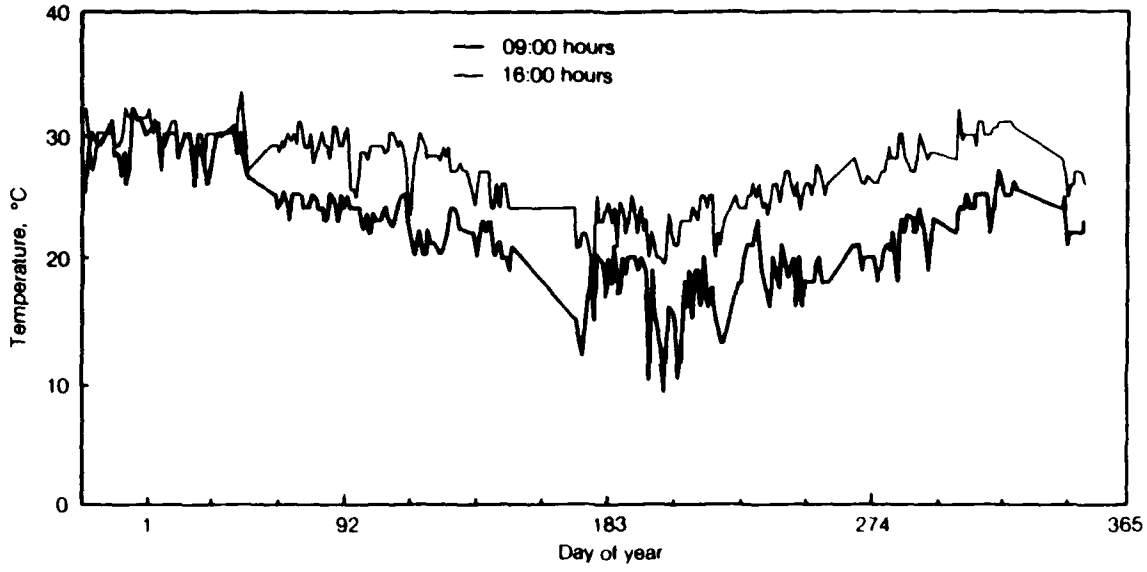

Figure 1: Daily temperature at Townsville store.

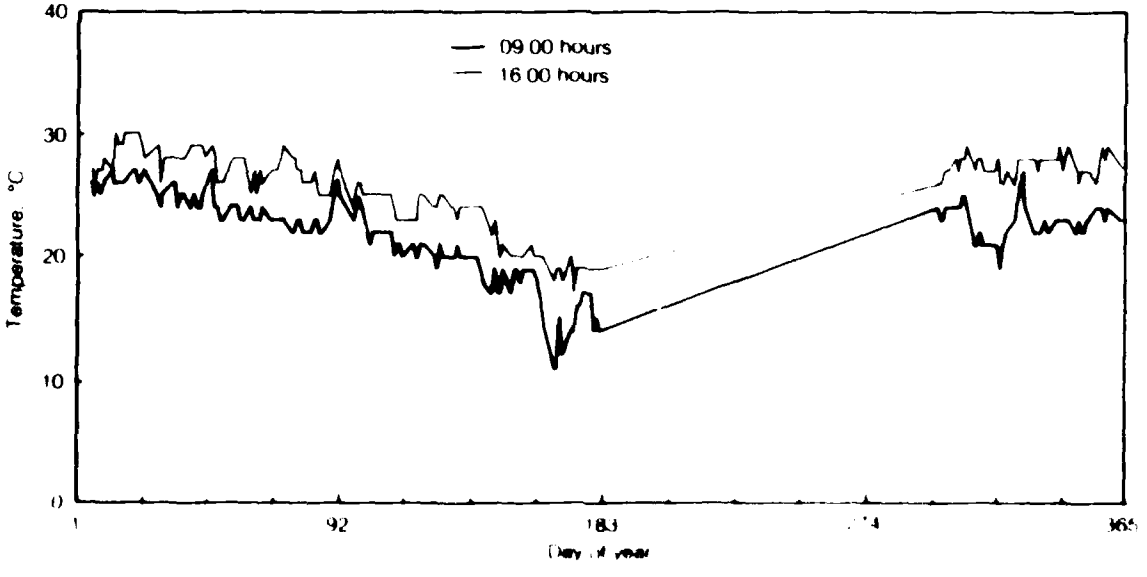

Figure 2: Daily temperature at Ashgrove store

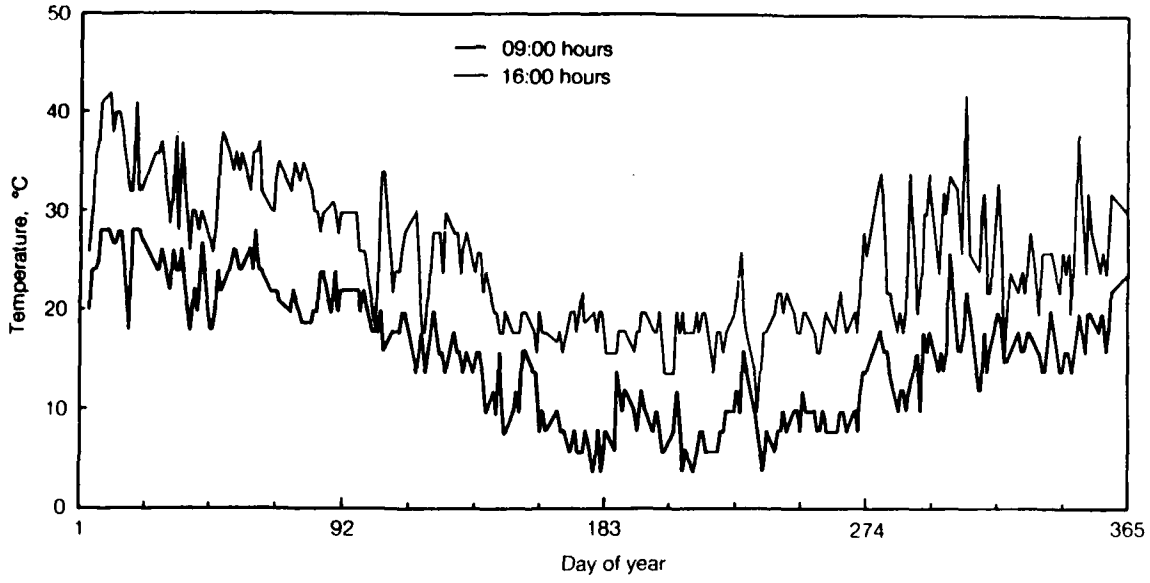

Figure 3: Daily temperature at Liverpool store.

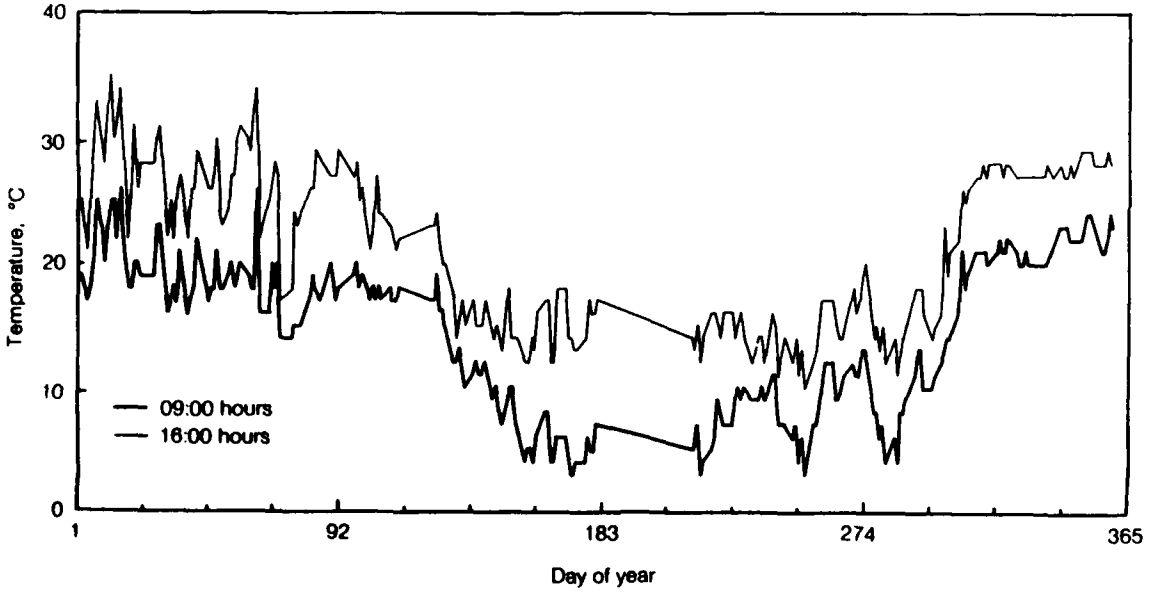

Figure 4: Daily temperature at Puckapunyal store.

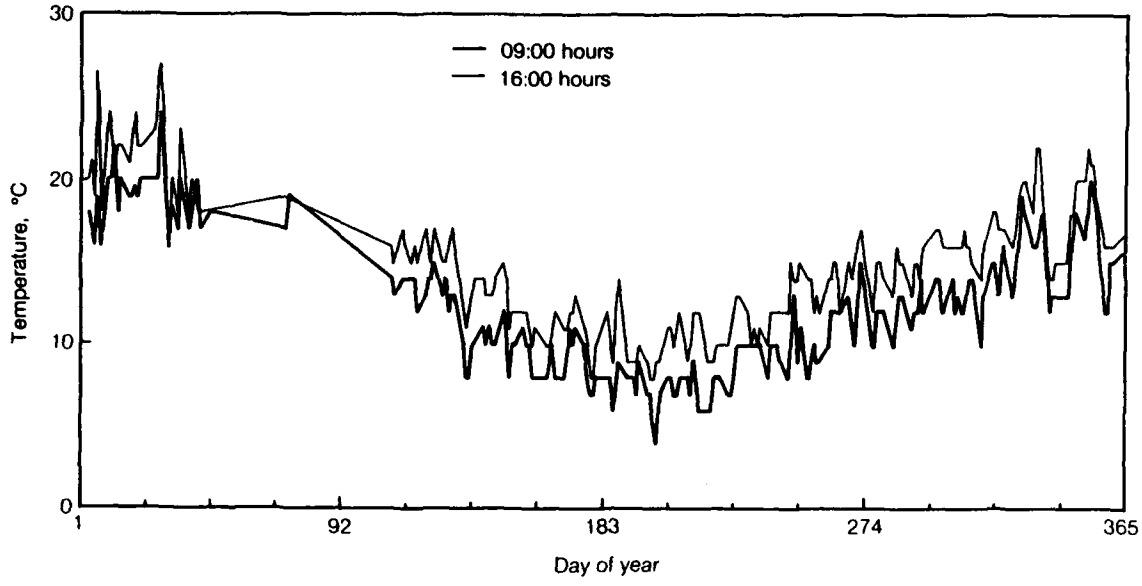

Figure 5: Daily temperature at Hobart store.

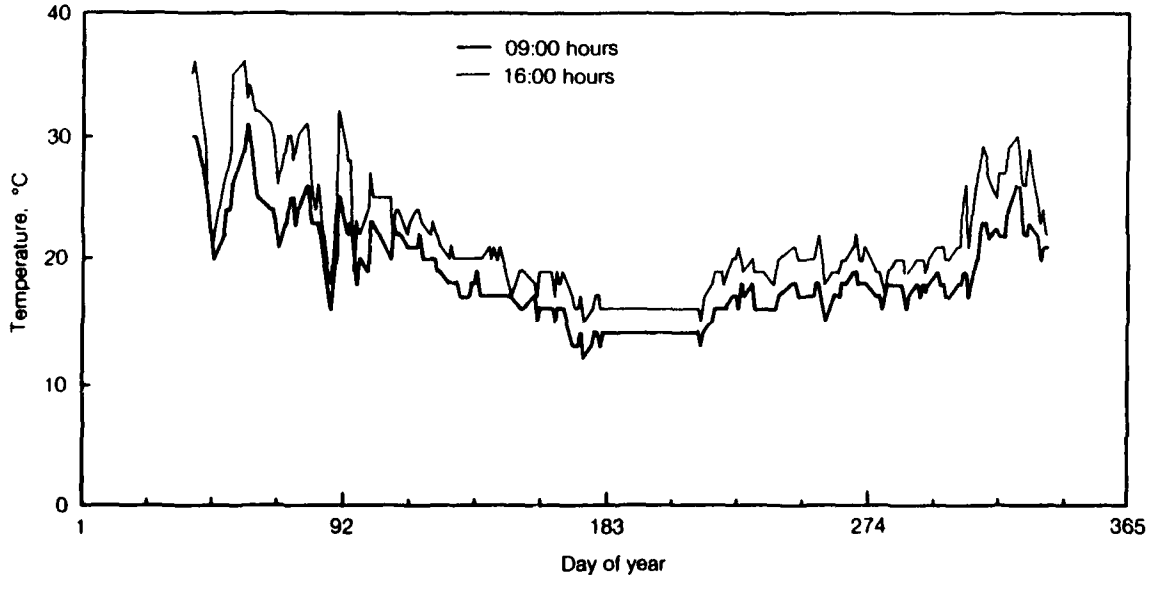

Figure 6: Daily temperature at Karrakatta store.

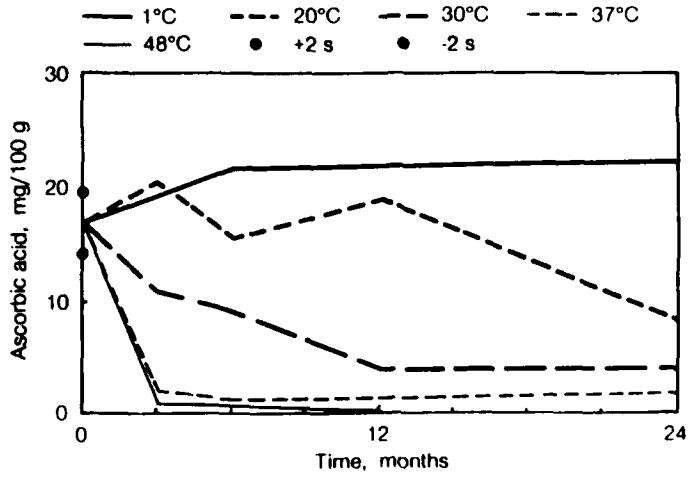

Figure 7: Chocolate with encapsulated ascorbic acid added before refiner.

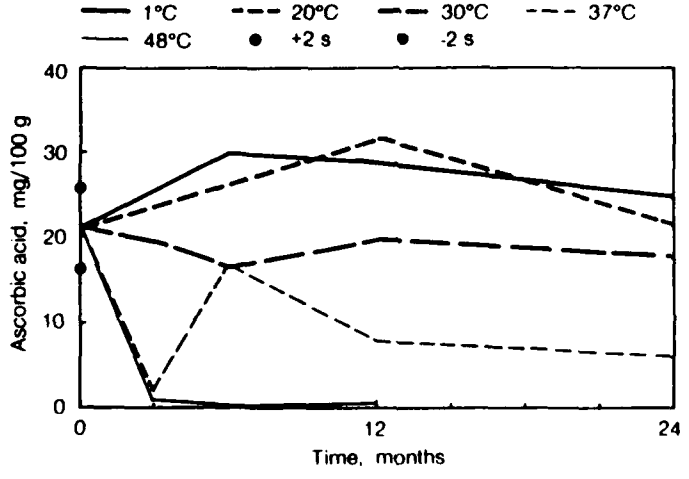

Figure 8: Chocolate with encapsulated ascorbic acid added after refiner.

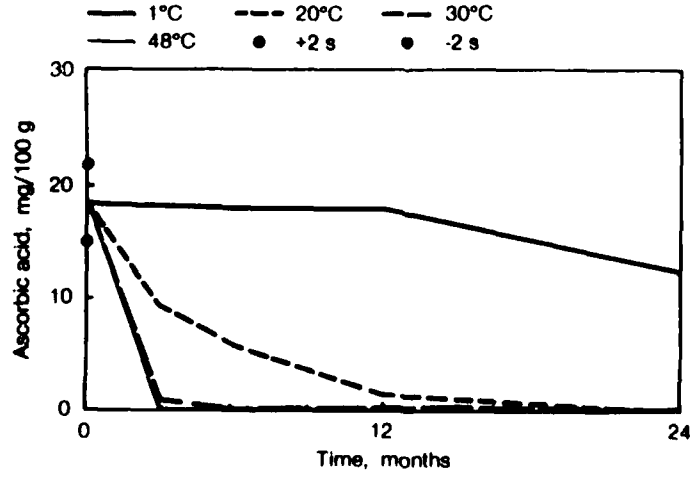

Figure 9: Chocolate with ascorbyl palmitate.

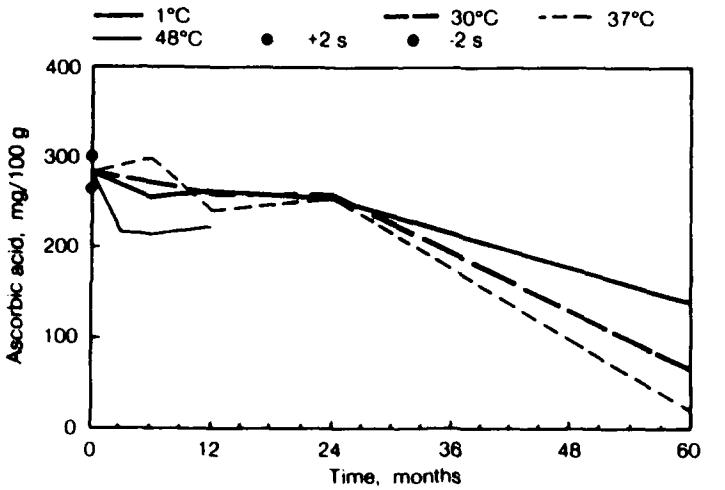

Figure 10: Fruit candy with ascorbic acid.

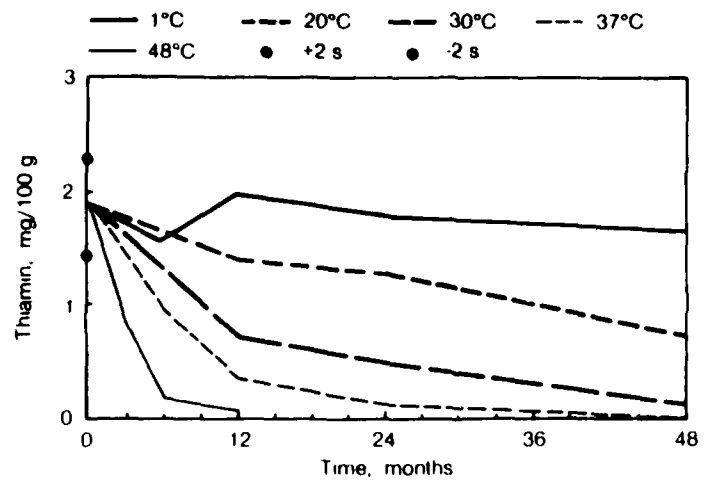

Figure 11: Thiamine in IMCR chicken and vegetables.

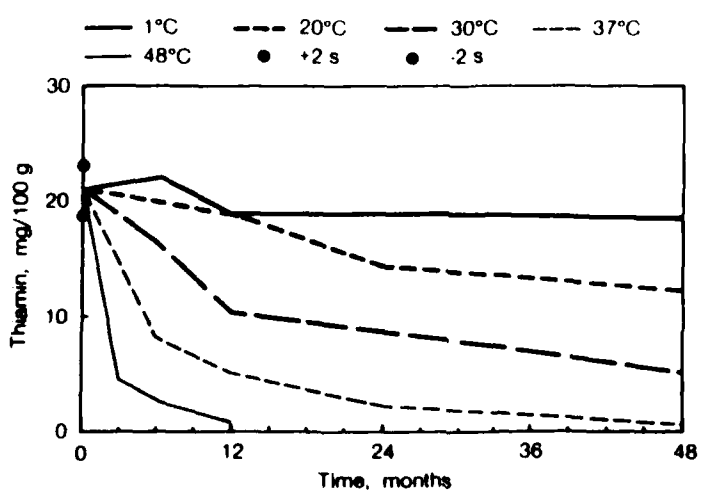

Figure 12: Thiamine in beef noodle soup powder.

Table 4: *Initial vitamin concentrations of fortified components mg/100 g*

Component	N	Ascorbic Acid		Thiamine		Riboflavin		Niacin	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
EFR Trial									
Chocolate	3	25.2	1.5	3.54	0.41				
Instant Coffee	4	671	112	2.82	0.71				
Fruit Candy	3	284	11						
Encapsulated Ascorbic Acid Fortified Chocolate									
Before Refiner	9	16.1	1.3						
After Refiner	9	21.1	2.2						
Ascorbyl Palmitate Fortified Chocolate									
After Refiner	10	18.1	1.7	3.11	0.11				
IMCR Main Meals									
Beef Tortellini	4	9.0	6.4	0.012	0.007	0.123	0.046	2.07	0.44
Chicken & Vegetables	4	18.7	5.7	1.88	0.25	0.455	0.057	6.24	0.48
Beef Meat Balls, Bacon and Vegetables	4	0.95	0.70	0.038	0.026	BL	BL	1.28	0.17
Beef Meat Balls with Sweet & Sour Sauce	4	3.1	1.9	0.023	0.015	0.055	0.068	0.89	0.13
Lamb and Vegetables with Rosemary	4	21.9	3.4	0.073	0.029	0.24	0.08	3.1	1.2
CR10M									
Beef Noodle soup powder	4	102	5.7	21.2	1.15	4.52	0.91	33.5	2.8
Chicken Noodle soup powder	4	123	9.9	5.3	0.66	5.68	0.33	34.0	2.7
Tomato soup powder	4	316	37.0	5.82	0.44	5.35	0.20	39.9	0.14
Pea & Ham soup powder	4	150	6.4	5.77	0.34	4.96	0.74	38.8	2.4
Unsweetened Condensed Milk	4	51.2	2.2						

N = number of samples, BL = Below Detection Limit

3.1.1 EFR Trial

Initially, the three fortified components were found to contain the specified concentration of ascorbic acid (Tables 3 and 4). *Chocolate* was found to contain the specified concentration of thiamine (Table 3) but *instant coffee* was found to contain only about 10% of the specified concentration. The variation in initial concentrations were of the order of 10% of the mean in *chocolate* and *fruit candy*, but was of the order of 20% in *instant coffee*. The variation in *coffee* was not due to the analytical method (verified by replicate determination) but represents the variation in fortification levels, probably due to manufacture by dry blending of the powdered ingredients and the small quantity (7 g) in each sachet.

3.1.2 *Encapsulated Ascorbic Acid Fortified Chocolate Trial*

The initial concentrations of ascorbic acid (Table 4) were found to be lower in those fortified before refining than in those fortified after refining ($t = 4.9$, $p = 0.000085$). This indicates that processing the *ration chocolate* has destroyed approximately a quarter of the ascorbic acid added. However, the standard error of two sets of initial concentration results (Table 4) show that the variation in ascorbic acid concentration is greater in the *chocolate* fortified after refining ($F = 23.7$, $p = 0.00017$). That is, the ascorbic acid fortification is not as evenly distributed when added at the conching stage after refining.

3.1.3 *Ascorbyl Palmitate Fortified Chocolate Trial*

The initial concentrations of ascorbyl palmitate as ascorbic acid (Table 4) were found to be under the specification (Table 3) and intermediate compared with the encapsulated ascorbic acid fortified *chocolates*. The standard error was also intermediate compared with the encapsulated fortification, even though ascorbyl palmitate is fat soluble and should be easily distributed throughout the fat.

3.1.4 *IMCR Main Meal Trial*

The initial vitamin concentrations (Table 4) show that none of the meals were fortified at the specified level (Table 3). Most were found to contain only natural levels. *Chicken & vegetables* has been fortified with ascorbic acid, riboflavin, thiamine and niacin, but only thiamine was found to meet the specification (Tables 3 & 4). *Lamb & vegetables with rosemary* has been fortified with ascorbic acid, but failed to meet the specification (Tables 3 & 4). This study used the first procurement of these meals and it is understood the manufacturer had difficulty obtaining the vitamin concentrate to fortify the meals. The manufacturer has continued to fail to achieve the specified vitamin concentrations in these meals (Table 6 & Appendix D).

The standard deviation of the initial concentration for each of the vitamins was relatively high, due to the dependence on natural levels, which are inherently variable. In many cases (Table 4) the standard deviation was a very large proportion of the mean concentration. Thus, the vitamins were not evenly distributed in the various cans of each IMCR main meal. The ascorbic acid concentration of *chicken & vegetables* and *lamb & vegetables with rosemary* had relative standard deviations which were smaller than found in the other meals. The other vitamins in *chicken & vegetables* also had smaller relative standard deviations.

3.1.5 *CR10M Soup Powder Trial*

The initial concentrations (Table 4) show that all powders were fortified with an excess of thiamine. Only *beef noodle soup* was marginally deficient in ascorbic acid. *Beef noodle* and *pea & ham* were deficient in riboflavin, while *beef noodle* and *chicken noodle* were deficient in niacin.

3.1.6 *CR10M Unsweetened Condensed Milk Trial*

The initial concentration of ascorbic acid (Table 4) was found to be below the specified concentration (Table 3), but the standard deviation was small with respect to the mean initial concentration.

3.2 *Niacin Stability Study*

Changes in niacin concentrations did not correlate well with time or temperature for IMCR *chicken & vegetables* and *lamb & vegetables with rosemary*, CR10M *tomato, beef noodle, chicken noodle* and *pea & ham soup* powders. The regression coefficients (r^2) were less than 0.34 for all carriers examined, *tomato soup* being the highest. The reaction rate constants (A) were relatively close to 1 (2E+1 to 4E+5). This indicates that the data did not fit the exponential model very well. There were also poor correlations with linear models ($r^2 < 0.4$). Examination of the data (Appendix A) shows that there was a wide variation in the values for each time – temperature point. In some cases (IMCR *chicken & vegetables*, CR10M *beef noodle soup powder*) the later results were higher than the initial results, suggesting that there are no differences and the sets of time – temperature points are from the same populations. Thus, it may be concluded that niacin was relatively stable during storage in all items examined. The 1987 CR1M (Appendix B, on microfiche) was initially only analysed for niacin in items with a specification. After storage, these items have concentrations of the same order, supporting this conclusion.

3.3 *Riboflavin Stability Study*

Initial riboflavin concentrations in IMCR meals (Table 4) were generally adequate for nutritional needs, but the considerable variation (12.5 to 123% of mean) make interpretation difficult. Trends were inconsistent with respect to temperature and time due to the relatively large standard deviation (Table 4). The regression coefficient (r^2) for chicken & vegetables was 0.1 for the exponential model and less than 0.04 for the linear models tested. The value for A was 2E+1, relatively close to 1, indicating good storage stability. Examination of the data (Appendix A) shows that there was a wide variation in the values for many time – temperature points. Some of the later values were higher than the initial values, which suggests that there are no differences and the set of time – temperature points are from the same population. This leads to the conclusion that significant levels of riboflavin would be available after two to three years storage without fortification.

Examination of the data for riboflavin concentrations in soup powders (Appendix A) shows that there was a wide variation in the values for many time – temperature points. In some cases the later values are higher than the initial values, suggesting that there are no differences and the sets of time – temperature points are from the same populations. This leads to the conclusion that riboflavin is stable and the soup powders were likely to retain the required level after 4 years normal storage.

Riboflavin concentrations found in the 1987 CR1M after storage showed a general small decline but are considered consistent with the above conclusions.

3.4 *Ascorbic Acid Stability Study*

Ascorbic acid had very poor storage stability in EFR *ration chocolate* (Appendix A), which confirms the conclusion that the stability of ascorbic acid in *chocolate* was unsatisfactory (James *et al.*, 1986). The regression analysis based on the exponential model (Table 5) was a poor fit ($r^2 = 0.47$) to the exponential model (equation 3). However, a strong correlation ($r^2 = 0.89$) was found using a zero order, linear model ($x = 3.67 - 0.016T - 0.041t - 0.024rh$). The manufacturer was asked to prepare ration chocolate fortified with encapsulated ascorbic acid and ascorbyl palmitate.

Table 5: *Degradation reaction equation coefficients*

Component	Ascorbic Acid				Thiamine			
	a mg/100 g	A	E k/mol^{-1}	r^2	a mg/100 g	A	E k/mol^{-1}	r^2
EFR Trial								
Chocolate	37.3	1E-9	-47.7	0.47	4.1	1E-5	-23.4	0.02
Instant Coffee	800	2E+2	14.7	0.07	2.9	1E+2	16.3	0.30
Fruit Candy	350	4E+1	17.6	0.23				
before refiner	25.7	8E+9	62.0	0.79				
after refiner	34.9	6E+8	56.5	0.62				
24 month excluded	34.9	3E+9	59.4	0.66				
Chocolate with Ascorbyl palmitate	19.9	1E+15	88.2	0.89	4.1	1E+11	73.2	0.56
IMCR meals								
Chicken and vegetables	27	1E+3	21.3	0.30	2.1	2E+8	53.6	0.82
6 month excluded	27	4E+3	24.7	0.50	2.1	3E+9	61.5	0.95
Lamb and vegetables with rosemary	25	9E-9	-40.6	0.25				
6 month excluded	25	1E-5	-22.6	0.09				
CR10M								
Beef noodle soup powder	133	2E+3	29.7	0.25	24.2	2E+9	59.9	0.81
Chicken noodle soup powder	136	6E+7	54.0	0.56	6.1	4E+5	40.2	0.75
Pea and Ham soup powder	157	7E+3	33.1	0.38	6.9	2E+7	52.3	0.75
Tomato soup powder	380	2E+8	56.1	0.76	7.7	2E+3	28.0	0.23
Unsweetened condensed milk	54	1E+8	53.2	0.77				

Regression of $\log_e(\log_e(a/x)) - \log_e(\text{time}) = \log_e(A) - E/RT$

- a = Initial concentration used for statistical analysis.
- x = Concentration found at the time (months) and temperature T.
- A = Frequency factor or reaction rate constant.
- E = Activation energy calculated from regression equation. Literature values for ascorbic acid = 96.7 kJ mol^{-1} and thiamine = 113 kJ mol^{-1} (De Ritter, 1982).
- R = Gas constant = 8.314 kJ mol^{-1} K^{-1}.
- r^2 = Square of regression coefficient for equation.

The results for fortification with encapsulated ascorbic acid before refining are displayed with respect to time and temperature in Figure 7, which shows that there was a dramatic change in stability of ascorbic acid as the temperature increased above 20°C. The ascorbic acid concentration after three months at 37°C and 48°C declined virtually to zero. Regression analysis of these data against the exponential model (Table 5) shows a reasonable fit with an estimated initial

concentration higher than found (Table 4), an E value approaching the literature value (96.7 kJ mol^{-1}, DeRitter, 1982) and a very high value for A. The estimated initial concentration could be a better estimate of the concentration at the time of manufacture (May 86) as the initial concentrations (Table 4) were determined on delivery (Sept 86) after 4 months storage at unknown temperatures (probably 10°C to 25°C) during transit. During transit there may have been differences in storage treatment with some cases being exposed to sun and others being sheltered giving rise to some of the variation.

The *chocolate* fortified after refining at the conching stage (Fig. 8) shows better stability at 20°C, 30°C, and 37°C but similar stability at 48°C. Regression analysis of this data (Table 5) shows a poorer fit to the exponential model with a higher estimated initial concentration than found, an E value lower than for the before refiner value, a lower A value and a poorer regression coefficient. This batch of *chocolate* was manufactured at the same time as the *chocolate* fortified before refining and was delivered at the same time. Therefore, the estimated initial concentration may be a better estimate of concentration when manufactured. Excluding the 24 month points improved the fit, but it was still worse than the before refiner regression. Fortification after refining was expected to prevent the micro--encapsulation from being disrupted during processing leading to better stability. This data suggests that there is a plateau effect for encapsulated ascorbic acid added after refining and stability is better than when added before refining.

Contrary to expectation from the literature (Hung, Seib and Kramer, 1987) fortification with ascorbyl palmitate did not lead to improved storage stability (Fig. 9). Statistical analysis (Table 5) shows the best fit to the exponential model ($r^2 = 0.89$), an E value close to the theoretical value, a very large A value, and an estimated initial concentration close to the expected value (Tables 3 and 4). This chocolate was received the same month (May 88) as the manufacturing date and therefore there was no opportunity for uncontrolled storage effects to intrude on the trial.

The ascorbic acid concentration found in stored 1987 CR1M ration chocolate was 78% of the concentration found when examined initially (Appendix B). This result is consistent with the storage trial results discussed above.

This ascorbic acid degradation is of concern since it shows that only very short periods of high temperatures, as occurs in the main ration warehouses (Fig. 1 to 6) during summer, will be sufficient to deplete much of the ascorbic acid fortification. It shows that ascorbic acid in all the available forms for fortification becomes increasingly unstable as the temperature increases above 20°C. *Chocolate* fortified with encapsulated ascorbic acid at the conching stage demonstrated the best storage performance for ascorbic acid. As *ration chocolate* is one of the most acceptable items to users (Forbes-Ewan & Waters, 1986) and it is used as an emergency ration, it is desirable to continue to fortify it with ascorbic acid. The best strategy would be to fortify with encapsulated ascorbic acid after refining at a level sufficient to ensure adequate levels remain after storage.

The results for EFR *instant coffee* were much more difficult to interpret due to the inherent variation (ca 20%) between individual 7 g packs. The moisture (Appendix A) exceeds the specification (4%; DPI, 1984/8, 8-1-7). James *et al.* (1984) report the initial moisture in this batch of *instant coffee* as being 3.52 and 4.03%. This may have contributed to the loss of ascorbic acid, but only one group mean of *coffee* had a moisture within specification limits and it was not possible to compare the effect of low moisture *coffee* with high moisture *coffee*. Earlier reports (James *et al.*, 1982; James and Forbes-Ewan, 1981) list *coffee* as failing the

specification with moisture up to 8.85%. This suggests that the barrier properties of the packaging should be investigated.

The *instant coffee* used in the 1987 CR1M were found to meet the specification after storage, however, the ascorbic acid concentration was 78% of that found initially. The moisture content was less than 3% in both cases. This is consistent with the decline in concentration found with other products such as *ration chocolate*.

Ascorbic acid has good stability in EFR *fruit candy* (Fig. 10). Regression analysis shows a poor fit to the exponential model, but the estimated initial concentration was higher than, but consistent with, the value found (Table 4). The E value was very low and the A value was relatively close to zero. A stronger correlation ($r^2 = 0.46$) was found for the zero order linear model ($x = 302 - 2.58t - 0.97T$) with no significant correlation with relative humidity. This behaviour was similar to that observed for riboflavin and niacin.

Fruit candy stored with the 1987 CR1M shows support for this conclusion with a concentration higher than that found initially (Appendix B), However, the difference may be due to use of another batch (no batch codes) of *candy* in the stored ration, which may have been fresher when packaged.

Ascorbic acid concentrations were close to the normal reporting limit of 1 mg/100 g in the IMCR meals (Table 4) *beef meat balls, bacon & vegetables* and *beef meat balls with sweet & sour sauce*. Since these values are barely above reporting limits they could not be regarded as good indicators of the storage stability of ascorbic acid in these foods. Furthermore, the standard deviation of the initial concentrations were of a similar magnitude to the change in concentration correlating with time; which was also noted in *beef tortellini*, where the standard deviation of the initial concentration was 71% of the mean. The meals were manufactured (February/March/April 85) four to five months prior to receipt and commencing the storage trial. During this period they were subjected to unknown storage conditions, which may have contributed to some of the variation in initial concentration. In the other two meals the six month points were close to the detection limit. Regression analysis of the data shows an improvement in the regression coefficient (r^2) for *chicken & vegetables* when the 6 month points were excluded (Table 5). Inspection of these samples showed that they had been overheated at some stage during the trial, being very dark in colour, therefore, these points were excluded. Both sets of data were found to fit a linear model ($x = 14 - 0.2T - 0.3t$) with r^2 for *chicken & vegetables* of 0.49 and 0.43 for *lamb & vegetables with rosemary*. The *lamb & vegetables with rosemary* linear fit was better than the exponential model. Overall, the results indicate that these meals were poor carriers for ascorbic acid fortification.

Beef tortellini, chicken & vegetables and *lamb & vegetables with rosemary* included in the revised CR1M were initially fortified at 2/3 the concentration required by the specifications (Table 6 and Appendix D). After warehouse storage, these items were found to have virtually no ascorbic acid remaining, supporting the storage trial conclusions.

Of the soup powders (Appendix A), only the *chicken noodle soup* ascorbic acid concentration had declined significantly below the specified level (Table 3). This was partially due to *chicken noodle* being fortified only 16% above the specified concentration (Tables 3 and 4), while the *pea & ham* and *tomato soups* were fortified substantially above the specified level. The regression coefficients for the exponential model for the soup powders (Table 5) ranged from an insignificant value for *beef noodle soup* to a significant value for *tomato soup*. All estimated initial

concentrations (Table 5) approximated the actual initial concentrations (Table 4). *Chicken noodle soup* and *tomato soup* had A values of the order of the values obtained for *chocolate*. while the values for *beef noodle* and *pea & ham soup* were closer to the value obtained for *fruit candy*. The partial regression for time was not significant, most of the change was explained by the change in temperature. The regression coefficient (r^2) for the zero order linear model ranged from 0.15 for *beef noodle soup* to 0.87 for *tomato soup*, only the *beef noodle soup* regression was worse than the linear model. Only *chicken noodle soup* showed a significant correlation with humidity (partial $r^2 = 0.11$, $x = 216 - 0.33t - 2.76T - 0.86rh$) but was insignificant with respect to time. Thus, two of these dry powders demonstrate much better performance as carriers for ascorbic acid than IMCR meals or ration chocolate. The result for *tomato soup*, however, compares poorly with 90% retention in tomato flakes claimed by Kramer (1982). It could be concluded that the type of soup powder chosen as the carrier has a very significant influence on the degradation of ascorbic acid in soup powders, *beef noodle* and *pea and ham* being the best carriers. Alternatively, there may be a difference in the quality of packaging seal achieved, allowing ingress of oxygen and moisture. This would be more consistent with the results quoted for different tomato products (Kramer, 1982) but the partial regression coefficient for humidity was not significant in *tomato soup* powder.

The 1987 CR1M soup and gravy bases were not fortified with ascorbic acid. However, the beef flavouring and chicken flavouring included with the *instant noodles* were found to retain a concentration of around 6 mg/100 g after storage. This suggests that these dry flavourings will stabilise ascorbic acid. This is inconsistent with some of the results above, and supports the hypothesis of oxygen leaking into some soup powder packages but not others, due to ineffective seals.

The results show that ascorbic acid was unstable in *unsweetened condensed milk*. The regression coefficient (Table 5) shows a reasonably good fit to the exponential model with an estimated initial concentration close to the actual value obtained (Table 4), A was of similar order to that for the *chocolates*, but E was about half the theoretical value. The zero order linear model was found have a regression coefficient (r^2) of 0.75, as good a fit as the exponential model. This suggests that another model, such as a second order model with dissolved oxygen as the other rate limiting parameter, may be more appropriate. Dissolved oxygen was not measured during this study and thus this model cannot be tested. However, the values for this regression were of a similar order to those for the IMCR meals and *ration chocolate*. A similar effect (Table 5) to that found for ascorbyl palmitate fortified chocolate was apparent, that is, a short period of high temperature, such as experienced during summer, will reduce ascorbic acid below the level required for nutritional needs.

Sweetened condensed milk included in the 1987 CR1M was found to retain 80% of the ascorbic acid concentration found initially, however, the samples were from different batches. This result is consistent with the storage trial results on *unsweetened condensed milk*.

The fruit drink powders used in the 1987 CR1M were all found to meet specification after warehouse storage for a year. Some concentrations were greater than initial concentrations (batch codes were the same), probably due to the variation inherent in packaging single serve quantities of a dry mix product. These results suggest that these powders may have good storage properties for ascorbic acid, provided a good package seal is achieved.

The fruit jams used in the 1987 CR1M were found to meet specifications after warehouse storage for a year. The ascorbic acid concentrations, with one exception, were 50% or less, of the concentration found initially (Appendix B). Initial concentrations were sufficient to provide half the recommended daily intake (Table 1). This had been reduced to a quarter of the recommended intake after a year. Storage for a further year at 20°C or higher would result in further decline to one eighth of the recommended intake or less, based on a twelve month half life for ascorbic acid in these products.

Fruit candy, beef noodle soup powder and *pea & ham* soup powder demonstrated better performance as carriers for ascorbic acid than the other products. The ascorbic acid can be expected to remain at sufficient concentration to contribute significantly to nutritional needs after storage for at least two years, as required (DLD, 1983). The discrepancy in performance between soup powders may be due to poor sealing, leading to ingress of oxygen and moisture, which requires investigation.

Fortification at a high level to compensate for the effects of storage appears to be a practical strategy to ensure adequate levels are present for the user.

3.5 *Thiamine Stability Study*

Recovery trials for thiamine in *coffee* during analysis of the EFR *instant coffee* samples, revealed that the AOAC method was unreliable and also led to doubt concerning the results for *chocolate*. This led to investigation of methods for thiamine determination and the adoption of the method of James & Hancock (1989). Thiamine determinations on EFR components were discontinued after the twelve month results due to the poor recovery.

The initial thiamine concentration in the EFR *instant coffee* (Table 4), determined by the AOAC method, was only 10% of the value required by the ADFFS (DPI, 1984/8). Despite the low initial concentration and variability in initial concentration, the trial showed that thiamine rapidly declines to negligible concentrations at temperatures above 30°C (Appendix A). The data did not fit the exponential model well (Table 5), but the zero order linear model ($x = 2.1 - 0.02T - 0.1t$) was a better fit ($r^2 = 0.66$).

The *coffee* used in the 1987 CR1M was found to contain about half the specified concentration after storage, using the method of James & Hancock (1989). However, no detectable thiamine was found initially in the 1987 CR1M, but concentrations of 3.53, 11.26 and 22.7 mg/100 g were found in IMCR, PRPNG and CR10M *coffees* respectively (Appendix B, on microfiche), and all bore the same batch code. This is typical of the variation to be expected in such a dry mix product. Thus, this result does not allow a definitive conclusion to be drawn, but suggests that thiamine is not stable in *instant coffee*.

The results for thiamine in EFR *ration chocolate* were a poor fit to any of the models tested, including the exponential model (Table 5). The data (Appendix A) generally indicate relatively poor stability. The ascorbyl palmitate *ration chocolate* samples were found to contain significant thiamine. Regression analysis (Table 5) excluding the 6 month points showed a reasonably significant correlation to the exponential model with an A value consistent with poor stability. A strong correlation with respect to temperature but poor correlation with respect to time was found using the zero order linear model. There are insufficient time – temperature data points to draw a definitive conclusion, however, these data

suggest that significant degradation of thiamine commences between 20°C and 30°C and that above 30°C degradation becomes rapid.

Initially no thiamine was detected in the 1987 CR1M *ration chocolate* (batch code 067), but 5.32 mg/100 g was found in PRPNG *ration chocolate* (batch code 065). *Ration chocolate* thiamine concentrations have shown considerable variability (Appendix A), which has been noted in earlier reports (James et al., 1982). The *chocolate* from the 1987 CR1M (batch code 067) stored for one year in warehouses was found to contain thiamine in excess of the specified concentration. Thus, these results do not allow a definitive conclusion to be drawn. A batch of *chocolate* is normally fortified at the conching stage. Each batch consists of several conch loads. These results may be explained by some conch loads failing to receive fortification.

Mean thiamine concentrations were only marginally greater than the standard deviation in all IMCR meals (Table 4) except *chicken & vegetables* (Fig. 11), therefore, regression analysis was only possible with the *chicken & vegetables* data The effect of overheating on the 6 month sample data was not as significant for thiamine as for ascorbic acid, as it is more stable than ascorbic acid (r^2, Table 5). The regression coefficient (r^2, Table 5) for the exponential model was significant. The estimated initial concentration was close to the actual concentration (Table 4) However, the value for E was similar to those obtained for thiamine in *chocolate* and for ascorbic acid in *chocolate* and *milk*. These results (Fig. 11) suggest that thiamine concentration would not be likely to decline below levels necessary to meet nutritional needs in meals fortified at the specified level (Table 3) within two to four years at less than 30°C.

Beef tortellini and *lamb & vegetables with rosemary* included in the 1987 CR1M both failed to meet the specification. Thiamine was found at a little higher concentration in *lamb & vegetables with rosemary* compared with the concentration found initially, while *beef tortellini* was half that previously reported. This is consistent with natural levels in these meals and reflects the natural variation *Chicken & vegetables* was fortified and still passed specification. These results tend to support the results obtained in the storage trial.

Thiamine was found to be unstable in all the soup powders (Appendix A). The regression coefficient (r^2, Table 5) for the exponential model was insignificant for *tomato soup* powder and significant for the other soup powders. The estimated initial concentrations (a) were close to the actual initial concentrations (Table 4), suggesting some validity for the model. The E values were half the literature value (113 kJ mol^{-1}, De Ritter, 1982), or less. *Beef noodle soup* data (Fig. 12) fitted the zero order linear model better ($r^2 = 0.88$, $x = 26 - 0.12t - 0.45T - 0.03rh$). *Chicken noodle soup* ($r^2 = 0.70$), *pea & ham soup* ($r^2 = 0.51$) and *tomato soup* ($r^2 = 0.31$) were equivalent fits to the exponential models. The coefficients for time, temperature and humidity became smaller in the same order as the regression coefficients. Thus, *beef noodle soup* performed worst as a carrier for thiamine and *tomato soup* performed the best. The results lead to concern that in soup powders, fortified at the specified level of thiamine, will decline to barely adequate nutritional levels over a two year storage period in mainland warehouses. It is recommended that the specification be increased to 25 mg/100 g (250 mg/kg) to ensure sufficient remains after four years storage to contribute significantly to nutritional needs.

Only the *beef soup & gravy base* included in the 1987 CR1M was fortified and met the specification after storage. The initial value obtained was lower and reflects the variation due to a single serve, dry mix powder. The beef flavouring included with the *instant noodles* was found to have significant thiamine (23 mg/100 g) after

storage. Unfortunately, no beef flavouring was included in any of the initial revised CR1M noodles. These results suggest that CR1M soup and gravy bases and instant noodle flavourings may be good thiamine carriers.

The cereal based items *muesli bars*, *cereal biscuits* and *survival biscuits* used in the 1987 CR1M all contained significant concentrations of thiamine after storage and were of the same order as the concentrations found initially. These items are not currently fortified, although some of the ingredients may have been. There are no specifications for thiamine in these items. These results suggest that cereal products may be suitable carriers for thiamine fortification.

The results of the storage trials suggest that thiamine fortification is worthwhile to offset the effects of storage.

3.6 *Compliance with Australian Defence Force Food Specifications (ADFFS)*

Table 6 lists those items for which a discrepancy was found between the results obtained during this evaluation, or the previous evaluation, and the specification (DPI, 1984/8). Table 6 also summarises the history of failures with respect to these items. A feature of the results with respect to specifications is that most of the items noted as failures in the last report have also failed in this report. CR10M soups have been noted as failures in Appendix B (on microfiche) but are not listed as failures in Table 6, as they have been purchased as unfortified items. Three items (*chewing gum*, *lifesavers*, and *butterscotch*) have been procured without a specification. It was therefore, not possible to evaluate compliance with specifications for these items. *Butterscotch* has, in the past, been evaluated with the *barley sugar* specification but has never passed this specification for moisture.

This report should be used as a guide in the selection of items to be sampled in the next procurement of Combat Ration items, and analysed according to the ADFFS (DPI, 1984/8) by the Australian Government Analytical Laboratories (AGAL). It should not be used as evidence in legal action against the companies who tendered the materials as it tests the goods at sampling levels below those recommended by the ADFFS, and in many cases with a considerable delay since procurement. Furthermore, some of the methods used in this evaluation are not those specified in the ADFFS (DPI, 1984/8), which would lead to considerable difficulty in sustaining the use of these methods in a legal context. Wherever possible, failures according to nutritional methods have been repeated by the method specified in the ADFFS (DPI, 1984/8).

Details of the results obtained from the AGAL laboratories for ration pack items over the period March 86 to April 87 are summarised in Appendices D and E (on microfiche). Appendix D summarises the results obtained on the canned meals for the IMCR ration, and the CR10M. Appendix E summarises the failures noted on the items which have been procured for many years and can be regarded as established items.

Table 6: Items failing to meet Australian Defence Force Food Specifications

Ration	Item	Specification Failed	Value of Specification	Result 1987	Result 1986	Result 1985	Result 1984	Result 1983
CR10M A	Whole Tomatoes	Ascorbic	>17.9mg/100g	8.7	2.4	1.9	9.0	11.7
	Whole Tomato Brine	Ascorbic		12.9	14.3	12.9	ND	9
	Beef Noodle soup powder	Ascorbic	>106mg/100g	0.3	2.9	pass	3.6	0.8
		Riboflavin	>5.2mg/100g	BL	BL	pass	0.19	0.10
		Niacin	>35.3mg/100g	0.4	1.8	18.0	0.93	1.0
	Spaghetti with Ground Meat	Moisture	<73%	76.3	77.3	pass	75.2	pass
CR10M ADE	Raspberry Jam	Ascorbic	>35mg/100g	34.8	pass	pass	pass	pass
CR10M BDE	Blackberry Jam	Ascorbic	>35mg/100g	32.0	pass	pass	pass	pass
CR10M BE	Tomato soup powder	Riboflavin	>5.2mg/100g	0.29	0.2	pass	0.28	0.29
		Thiamine	>5.2mg/100g	0.1	1.2	ND	0.08	0.08
		Niacin	>35.3mg/100g	1.8	1.6	pass	1.67	2.8
CR10M BC	Butter Concentrate	Moisture	<0.3%	0.34	0.53	pass	0.43	pass
CR10M C	Chicken Noodle soup powder	Ascorbic	>106mg/100g	0.6	2.6	pass	0.91	1.5
		Riboflavin	>5.2mg/100g	BL	0.15	pass	0.25	0.05
		Thiamine	>5.2mg/100g	0.008	0.26	ND	0.14	0.14
		Niacin	>35.3mg/100g	0.5	0.29	21.1	1.4	1.1
	Strawberry Jam	Ascorbic	>35mg/100g	29.7	pass	pass	pass	4
CR10M D	Beef and Vegetables	Moisture	<73%	74.8	74.0	74.5	74.6	81.8
	Pea & Ham soup powder	Riboflavin	>5.2mg/100g	0.17	0.08	pass	0.52	0.26
		Thiamine	>5.2mg/100g	0.57	2.5	ND	0.75	0.10
		Niacin	>35.3mg/100g	0.40	2.8	pass	2	1.8
CR10M E	Chicken and Vegetables	Moisture	<73%	76.6	77.5	77.3	ND	ND
		Ascorbic	>30mg/100g	4.8	1.1	6.3	ND	ND
		Niacin	>7mg/100g	5.8	pass	pass	ND	ND
		Riboflavin	>0.5mg/100g	0.19	BL	0.14	ND	ND
CR10Mcom	Tomato Sauce	Ascorbic	>66mg/100g	18.8	40.8	39.0	pass	35
CR1M com	Instant Coffee	Niacin	>140mg/100g	115	93	pass	pass	ND
		Riboflavin	>21.1mg/100g	18	pass	ND	pass	ND
		Thiamine	>21.1mg/100g	BL	17	ND	0.1	0.9
	Chocolate	Net Weight	>55g	52.9	pass	54.1	51.0	50.0
		Thiamine	>2.2mg/100g	BL	pass	ND	pass	pass

BL = Below Detection Limit ND = Not Determined

Table 6 (Contd): Items failing to meet Australian Defence Force Food Specifications

Ration	Item	Specification Failed	Value of Specification	Result 1987	Result 1986	Result 1985	Result 1984	Result 1983
CR1M A	Beef and Vegetables	Moisture	<73%	73.3	73.8	75.0	76.2	75.9
	Mushroom soup,gravy base	Ascorbic	>106mg/100g	3.8	ND	ND	ND	ND
		Niacin	>35.3mg/100g	2.2	ND	ND	ND	ND
		Riboflavin	>5.2mg/100g	BL	ND	ND	ND	ND
		Thiamine	>5.2mg/100g	BL	ND	ND	ND	ND
CR1M AB	Freeze-Dried Rice	Moisture	<2%	3.5	pass	pass	pass	pass
CR1M AD	Orange Beverage powder	Ascorbic	>200mg/100g	130	pass	pass	103	175
CR1M B	Tomato soup,gravy base	Ascorbic	>106mg/100g	BL	ND	ND	ND	ND
		Niacin	>35.3mg/100g	1.1	ND	ND	ND	ND
		Riboflavin	>5.2mg/100g	0.48	ND	ND	ND	ND
		Thiamine	>5.2mg/100g	BL	ND	ND	ND	ND
CR1M B	Lamb and Vegetable	Moisture	<73%	73.4	75.2	76.6	ND	ND
	with Rosemary	Ascorbic	>30mg/100g	22.9	0.76	0.93	ND	ND
		Niacin	>7mg/100g	5.2	5.3	3.0	ND	ND
		Riboflavin	>0.5mg/100g	0.30	0.36	0.35	ND	ND
		Thiamine	>0.4mg/100g	0.17	0.19	ND	ND	ND
CR1M BD	Muesli bars	Moisture	<7%	10.2	12.6	ND	ND	ND
CR1M C	Luncheon Meat Type II	Fat	<10%	11.3	11.8	10.4	15.0	11.7
	Pea & Ham soup,gravy base	Ascorbic	>106mg/100g	BL	ND	ND	ND	ND
		Riboflavin	>5.2mg/100g	0.96	ND	ND	ND	ND
		Thiamine	>5.2mg/100g	1.2	ND	ND	ND	ND
		Niacin	>35.3mg/100g	2.4	ND	ND	ND	ND
CR1M D	Potato & Onion Powder	Moisture	<5%	5.4	6.2	pass	pass	5.9
	Beef Minced With	Ascorbic	>30mg/100g	20.4	BL	0.87	ND	ND
	Tortellini	Niacin	>7mg/100g	4.7	3.1	1.8	ND	ND
		Riboflavin	>0.5mg/100g	pass	BL	0.14	ND	ND
		Thiamine	>0.4mg/100g	0.26	0.09	ND	ND	ND
	Beef soup,gravy base	Ascorbic	>106mg/100g	BL	ND	ND	ND	ND
		Niacin	>35.3mg/100g	0.8	ND	ND	ND	ND
		Riboflavin	>5.2mg/100g	0.41	ND	ND	ND	ND

BL = Below Detection Limit ND = Not Determined

Table 6 (Contd): *Items failing to meet Australian Defence Force Food Specifications*

Ration	Item	Specification Failed	Value of Specification	Result 1987	Result 1986	Result 1985	Result 1984	Result 1983
CR1M E	Chicken soup & gravy base	Ascorbic	>106mg/100g	BL	ND	ND	ND	ND
		Riboflavin	>5.2mg/100g	1.8	ND	ND	ND	ND
	Chicken and Vegetables	Moisture	<73%	76.4	76.7	77.7	ND	ND
		Ascorbic	>30mg/100g	20.6	7.1	0.5	ND	ND
		Riboflavin	>0.5mg/100g	0.37	0.3	0.4	ND	ND
PRPNG A	Beef Minced With Tortellini	Ascorbic	>30mg/100g	0.2	BL	0.9	ND	ND
		Niacin	>7mg/100g	4.8	3.1	1.8	ND	ND
		Riboflavin	>0.5mg/100g	0.22	BL	0.14	ND	ND
		Thiamine	>0.4mg/100g	0.37	0.09	ND	ND	ND
PRPNG C	Chicken and Vegetables	Moisture	<73%	76.0	76.7	77.7	ND	ND
		Ascorbic	>30mg/100g	0.5	7.1	0.5	ND	ND
		Niacin	>7mg/100g	5.9	pass	6.1	ND	ND
		Riboflavin	>0.5mg/100g	0.28	0.3	0.4	ND	ND
PRPNG com	Rice	Thiamine	>0.4mg/100g	0.4	BL	ND	ND	ND
		Riboflavin	>0.3mg/100g	0.12	pass	ND	ND	ND
	Instant Coffee	Niacin	>140mg/100g	47	50.7	57.9	ND	ND
		Riboflavin	>21.1mg/100g	16	17.1	ND	ND	ND
		Thiamine	>21.1mg/100g	11.2	BL	ND	ND	ND
		Ascorbic	>420mg/100g	238	51.0	pass	ND	ND
	Chocolate	Net Weight	>55g	52.0	51.3	53	ND	ND
		Ascorbic	>22mg/100g	19.8	21.1	pass	ND	ND
PR1M AD	Orange Beverage Powder	Ascorbic	>200mg/100g	ND	186	pass	95.4	pass
PR1M B	Lemon Beverage Powder	Ascorbic	>200mg/100g	ND	193	pass	pass	pass
PR1M CE	Lime Beverage Powder	Ascorbic	>200mg/100g	ND	155	pass	pass	pass
PR1M D	Veal Italienne	Moisture	<2%	ND	2.4	pass	ND	ND
PR1M	Tuna and Rice	Salt	<2.54%	ND	2.92	3.40	ND	ND
	Sweetened Condensed Milk	Fat	>9%	ND	9.0	8.7	ND	ND

BL = Below Detection Limit ND = Not Determined

Table 6 (Contd): *Items failing to meet Australian Defence Force Food Specifications*

Ration	Item	Specification Failed	Value of Specification	Result 1987	Result 1986	Result 1985	Result 1984	Result 1983
PR1M com	Chocolate	Net Weight	>55g	ND	51.8	50.5	51.0	50
		Ascorbic	>22mg/100g	ND	19.8	19.2	pass	14.4
	Survival Biscuits	Moisture	2.5 - 4.0%	ND	4.65	pass	ND	ND
	Instant Coffee	Ascorbic	>420mg/100g	ND	156	pass	pass	pass
		Niacin	>140mg/100g	ND	96.8	pass	pass	112
		Riboflavin	>21.1mg/100g	ND	15.4	ND	pass	18.8
		Thiamine	>21.1mg/100g	ND	15.3	ND	0.23	0.04
		Moisture	<4%	ND	5.2	pass	pass	pass
	Muesli bars	Moisture	<7%	ND	11.5	ND	ND	ND
IMCR A	Beef Minced With Tortellini	Ascorbic	>30mg/100g	3.3	BL	0.9	ND	ND
		Niacin	>7mg/100g	5.5	3.1	1.8	ND	ND
		Riboflavin	>0.5mg/100g	0.31	BL	0.14	ND	ND
		Thiamine	>0.4mg/100g	0.3	0.09	ND	ND	ND
IMCR B	Beef Meat Balls and Sweet & Sour Sauce	Ascorbic	>30mg/100g	0.32	BL	BL	ND	ND
		Niacin	>7mg/100g	2.8	2.9	0.9	ND	ND
		Riboflavin	>0.5mg/100g	0.28	0.22	0.30	ND	ND
		Thiamine	>0.4mg/100g	0.25	0.22	ND	ND	ND
IMCR C	Chicken and Vegetables	Moisture	<73%	79.8	76.7	77.7	ND	ND
		Ascorbic	>30mg/100g	5.5	7.1	0.5	ND	ND
		Niacin	>7mg/100g	6.9	pass	6.1	ND	ND
		Riboflavin	>0.5mg/100g	0.20	0.3	0.44	ND	ND
IMCR D	Beef Meat Balls with Bacon & Vegetables	Moisture	<75%	75.1	pass	76.1	ND	ND
		Ascorbic	>30mg/100g	0.8	BL	BL	ND	ND
		Niacin	>7mg/100g	3.3	4.7	1.2	ND	ND
		Riboflavin	>0.5mg/100g	0.09	0.27	0.11	ND	ND
		Thiamine	>0.4mg/100g	0.19	0.19	ND	ND	ND
IMCR E	Lamb and Vegetables with Rosemary	Moisture	<73%	pass	75.2	76.6	ND	ND
		Ascorbic	>30mg/100g	3.1	0.8	0.9	ND	ND
		Niacin	>7mg/100g	5.4	5.3	3.0	ND	ND
		Riboflavin	>0.5mg/100g	0.24	0.36	0.35	ND	ND
		Thiamine	>0.4mg/100g	pass	0.19	ND	ND	ND

BL = Below Detection Limit ND = Not Determined

Table 6 (Contd): *Items failing to meet Australian Defence Force Food Specifications*

Ration	Item	Specification Failed	Value of Specification	Result 1987	Result 1986	Result 1985	Result 1984	Result 1983
IMCR ACE	**Instant Coffee**	Ascorbic	>420mg/100g	335	218	408	ND	ND
		Riboflavin	>21.1mg/100g	5.5	17.7	14.2	ND	ND
		Thiamine	>21.1mg/100g	3.5	16.1	10.2	ND	ND
IMCR CE	Lime Beverage Powder	Ascorbic	>200mg/100g	194	163	161	ND	ND
IMCR AD	Orange Beverage Powder	Ascorbic	>200mg/100g	186	199	pass	ND	ND
IMCR B	Lemon Beverage Powder	Ascorbic	>200mg/100g	pass	185	pass	ND	ND

BL = Below Detection Limit ND = Not Determined

AGAL have a tendency not to adhere to the sampling plan as specified in the ADFFS Part D 0-1-1 (DPI, 1984/8). Some items have been sampled according to the sampling plan (i.e. 5 sub-samples) and then bulked for some determinations, which produces one average result representative of the 5 sub-samples. Other items, particularly the new meals, have been split into two groups. One (ca 3 cans) is used for the usual gauge pressure, head space, moisture, and fat determinations. The other (ca 2 cans) is analysed for the vitamins (thiamine, niacin, riboflavin and ascorbic acid). This does not comply with the requirement in that there are not the required 5 data points. The requirements of the ADFFS (DPI, 1984/8) were determined on the basis of the Australian Standard 1199-1972 in order to give the purchasing authority an acceptable probability of not accepting a batch with a chosen proportion of defective units. Reducing the number of sample points dramatically increases the probability of accepting a much higher proportion of defective units.

Gauge Pressure and head space are not tested during a nutritional evaluation. Items failing to meet these specifications are the most frequently quoted in Appendices D and E. There is concern that the method specified for gauge pressure does not require the use of a compensating pressure gauge, which will correct for the relative size of the space in the measuring gauge compared with the head space in the can being tested. There would be a significant error, particularly in smaller cans, if such a correction is not made. This is considered to be the main cause of the large number of failures for gauge pressure.

It is almost impossible to evaluate the results obtained for salt in relation to some specifications. This is due to these specifications being in terms of added salt rather than a final total. Some items, eg. IMCR/CR1M *chicken & vegetables* and *lamb & vegetables with rosemary*, are clearly meeting the original aim of less than 0.76% salt. Others, e.g. IMCR *meat balls with bacon & vegetables* (1.41%) and *meat balls with sweet & sour sauce* (2.25%), are much higher and exceed this aim. These items are also higher according to procurement testing (Appendix D). It is known that some salt is necessary to assist with the binding of the meat balls; significant amounts can also be included from other ingredients such as bacon and soy sauce. Thus, these two meals could have a very high 'natural' salt contribution and therefore would not fail on the basis of added salt. It would be much easier to assess this aspect if the specification were in terms of total salt, which would include any natural contribution.

Table 7 summarises the incidence of failures to meet specifications found by AGAL and this work. Six parameters, gauge pressure, head space, drained weight, nitrate, nitrite and specific gravity, are not normally determined by MRL-Tasmania as they are quality rather than nutritional parameters. AGAL testing is intended to screen out poor quality items. Therefore, there should be an improvement in the incidence of failures when the final accepted items are examined at MRL-Tasmania. There does appear to be a significant improvement in the failure rate with respect to moisture and salt. However, the remaining five parameters show no significant improvement, indeed, in some cases, there is a greater failure rate. This leads to concern that there is insufficient sampling during procurement to achieve the standard of quality required. A good quality assurance program can only be successful if it includes an adequate level of sampling and testing leading to rejection of components which fail.

Table 7: Incidence of failures to particular specification parameters

Parameter	Percentage of Items Failing		
		MRL-Tasmania	
	AGAL	1986	1987
Moisture	57	27	24
Fat	6	17	13
Ascorbic acid	81	56	64
Niacin	81	63	80
Riboflavin	86	79	92
Thiamine	67	68	64
Salt	36	17	8
Gauge Pressure	42	ND	ND
Head Space	0.5	ND	ND
Drained Weight	100	ND	ND
Nitrate	0	ND	ND
Nitrite	0	ND	ND
Specific Gravity	100	ND	ND

ND = Not Determined. AGAL results for March 1986 to April 1987.

All production at MRL-Tasmania met microbiological specifications, except a batch of *Tuna and rice*. Although it failed the specification for standard plate count, it was released as it passed all other microbiological specifications.

3.7 *Nutritional Evaluation*

Table 8 summarises the total energy and the proportion of energy derived from fat, carbohydrate and protein in the rations 1986 IMCR and revised CR1M. Table 9 summarises the contents of water, fat, carbohydrate, protein and salt in each pack. The values for each menu include the contribution from the common items, which have been separately listed. Table 10 summarises the contents of the vitamins ascorbic acid, thiamine, niacin and riboflavin in each pack. Table 11 summarises the contents of sodium (Na), phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), lead (Pb) and cadmium (Cd) in the revised CR1M. Appendix C (on microfiche) details the contents of these elements in the individual items of the revised CR1M. This is the second evaluation in respect of the new IMCR ration and the first evaluation of the CR1M with revised menus (Forbes-Ewan & Waters, 1986).

Table 8: *Combat ration results 1986 and 1987 procurements – total contribution of each item to energy*

Source	Fat	Carbohydrate	Protein	Energy
	%	%	%	kJ
1986 Procurement				
IMCR common items	11	82	7	830
IMCR A ration total	27	58	15	4230
IMCR B ration total	26	64	10	4030
IMCR C ration total	21	62	17	3900
IMCR D ration total	32	57	11	4220
IMCR E ration total	25	61	14	3950
1987 Procurement				
CR1M common items	30	60	10	5050
CR1M A ration total	28	61	11	12160
CR1M B ration total	26	61	13	12190
CR1M C ration total	32	56	12	13190
CR1M D ration total	28	62	10	11990
CR1M E ration total	23	63	14	12260

Table 9: *Combat ration results 1986 and 1987 procurements – total contribution of each item to proximates*

Source	Net weight	Moisture	Fat	Carbohydrate	Protein	Salt
	g	g	g	g	g	g
1986 Procurement						
IMCR common items	62	13	2	42	4	0.1
IMCR A ration total	406	180	31	153	37	2.4
IMCR B ration total	423	194	28	162	24	5.7
IMCR C ration total	409	186	22	150	40	2.6
IMCR D ration total	408	185	37	149	28	3.5
IMCR E ration total	406	190	27	149	33	2.2
1/3 Recommended Daily Diatary Intake per 75 kg Male at						
Grade 3 activity					23-38	5.0
Grade 2 activity					23-32	5.0
Grade 1 activity					23-29	1.9
Grade 0 activity					23	1.9
1987 Procurement						
CR1M common items	329	44	41	191	28	9.8
CR1M A ration total	1099	391	94	472	80	15.8
CR1M B ration total	1150	451	89	464	97	14.3
CR1M C ration total	1179	435	113	460	98	21.9
CR1M D ration total	1148	460	90	464	75	14.6
CR1M E ration total	1174	447	76	486	98	19.2

Table 10: *Combat ration results 1986 and 1987 procurements – total contribution of each item to vitamins*

Source	Thiamine mg	Ascorbic Acid mg	Niacin mg	Riboflavin mg
1986 Procurement				
IMCR common items	0.61	8	5	0.81
IMCR A ration total	0.85	37	13	0.81
IMCR B ration total	1.13	34	13	1.33
IMCR C ration total	5.57	48	23	1.47
IMCR D ration total	1.07	36	16	1.40
IMCR E ration total	1.05	41	18	1.64
1/3 Recommended Daily Dietary Intake per 75 kg Male at				
Grade 3 activity	0.53	13	9	0.63
Grade 2 activity	0.46	13	7	0.57
Grade 1 activity	0.40	13	7	0.50
Grade 0 activity	0.37	13	5	0.37
1987 Procurement				
CR1M common	0.09	74	ND	2.07
CR1M A Menu total	0.43	136	ND	2.60
CR1M B Menu total	0.91	256	ND	3.22
CR1M C Menu total	0.51	196	ND	2.30
CR1M D Menu total	1.97	246	ND	3.70
CR1M E Menu total	7.40	181	ND	3.70
1987 Procurement stored 1 year in warehouses				
CR1M common	3.91	42	12	1.62
CR1M A Menu total	4.30	88	19	2.25
CR1M B Menu total	4.83	183	34	3.12
CR1M C Menu total	6.95	177	24	2.10
CR1M D Menu total	5.52	179	33	3.53
CR1M E Menu total	13.67	115	39	3.90

ND = Not Determined, insufficient data.

Table 11: Combat ration one man 1987 ration – total metal content

	Na g	P g	Ca mg	Mg mg	Fe mg	Cu mg	Zn mg	Pb mg	Cd mg
Common	4.4	0.6	770	130	4	0.4	4	BL	BL
A Menu	7.7	1.4	1010	300	13	1.4	16	0.4	0.04
B Menu	8.5	1.7	1100	390	16	2.0	21	0.3	0.02
C Menu	8.8	1.1	950	250	9	1.1	12	0.2	BL
D Menu	7.2	1.3	1120	300	15	1.2	16	0.3	BL
E Menu	9.4	1.5	1050	330	14	1.4	12	0.3	BL

BL = All determinations below the detection limit.

3.7.1 1986 Individual Meal Combat Ration (IMCR)

The IMCR has been designed as a substitute meal when fresh rations are not available. It is expected to be used only in conjunction with fresh food from base kitchens, canned equivalents, or the CR10M ration. It has not been designed for use as a sole source of food for an extended period. Therefore, evaluation of the nutritional quality must be in terms of perceived requirements.

The energy content is less than one third of daily needs and would be an adequate replacement for any of the fresh meals, as the other meals would provide the opportunity to replace any energy deficit. The proportion of energy derived from fat is below 30% in most meals, which is less than current nutritional guidelines (FAO/WHO, 1978). The proportion of energy derived from protein (Table 8) varies from 10% to 17%, which is in keeping with the broad usage envisioned, particularly as it is likely to be used to replace a midday meal. The protein content (Table 9) is within the recommended range for all except the C menu which marginally exceeds the requirement.

The salt content (Table 9) exceeds one third of total daily needs, but, in most rations, would be an acceptable compromise with the requirements of manufacturing technology and the wide variety of operational requirements. The salt content of the B ration is excessive due to the high salt content of the *meat balls with sweet & sour sauce* meal (2.25%). This supports the conclusion that the salt content of this meal exceeds specification.

The vitamin content (Table 10) is not deficient despite the failure to fortify the main meal items to specification. This is because many of the main meal items have substantial quantities of vitamins naturally present. Most menus have around the recommended daily dietary intake for thiamine, ascorbic acid and riboflavin and at least half the recommended daily dietary allowance for niacin. This is in excess of the requirement normally associated with the energy content of the ration. The C menu has 5 times the thiamine content due to adequate fortification of the *chicken & vegetable* meal, which is closer to the design specification. The evidence to date, discussed above, shows that as expected, riboflavin and niacin are stable and that thiamine and ascorbic acid are unstable

during storage. Recent research (unpublished) has shown that there can be losses of one third of ascorbic acid and thiamine during normal cooking of fresh rations, and further decline in concentration of ascorbic acid during storage at serving temperatures to negligible levels after 2 hours. De Ritter (1982) has shown that losses of ascorbic acid (up to 91%) and thiamine (up to 85%) may be even greater depending on the cooking method. Thus, feeding "fresh rations" in the field may exacerbate rather than correct ascorbic acid and, possibly, thiamine deficiencies. Furthermore, operational needs may well cause IMCR to be used in conjunction with other ration packs. Thus, fortification with thiamine and ascorbic acid is necessary to ensure that sufficient remains to meet the user's needs over the storage life of the ration.

3.7.2 *Revised Combat Ration One Man (CR1M)*

CR1M has been designed as a sole food source for active soldiers for periods of up to 30 days in a war emergency (DOD, 1988). These users can be expected to expend energy at a rate exceeding a grade 2 level of activity (Table 1) and may often exceed a grade 3 level of activity (Morrissey *et al.*, 1989; Morrissey *et al.*, 1990).

The energy content of the ration (Table 8) is considerably less than that in the previous version of the ration (13,700 to 14,800 kJ, James *et al.*, 1988). The average energy content (12,358 kJ) is 1,442 kJ deficient with respect to a grade 2 level of activity, the minimum energy expenditure expected of users. This deficiency in energy would be the equivalent of 39 g of body fat lost per day. Over the period of a short patrol (5 days) one would not expect a serious loss of body mass, but as energy expenditure is likely to greatly exceed a grade 2 level of activity (Morrissey *et al.*, 1989; Morrissey *et al.*, 1990) there are likely to be significant losses in body mass by users. If the ration were used for the full war emergency period of 30 days, then there would be a serious loss of body tissue by users. These losses would eventually detrimentally affect combat performance of the users.

The proportion of energy derived from fat (Table 8) has been reduced to less than 30% (nutritional guideline FAO/WHO, 1978) in all but the C ration, with an increase in the proportion from carbohydrate. The average fat content has been reduced from 132 g (James *et al.*, 1988) to 92 g per ration pack (Table 9). The contribution of energy from protein (Table 8) is similar to that provided by the previous menus (10 to 14%, James *et al.*, 1988).

There are three factors contributing to the lower energy content of the revised CR1M. Firstly, some of the old components (e.g. *Luncheon meat type 1*) contained a higher proportion of fat and a lower proportion of moisture than the replacement components (e.g. *Beef & tortellini*). These old components were replaced due to poor user acceptability (Forbes-Ewan and Waters, 1986). Secondly, current manufacturing trends are toward the use of leaner meat cuts to reduce fat consumption in the general population. Thus, components prepared from these cuts will have lower fat and therefore lower energy content. Thirdly, some components exceed maximum moisture specifications (Table 6), which means that the energy content is diluted compared to the specification requirement.

The salt content (Table 9) has been reduced by 2 g in the new ration (average 17.2 g) compared with the previous version (19.4 g, James *et al.*, 1988). This approaches the desirable maximum of 15 g and two menus are less than this.

amount. The high salt in the C menu is largely due to the *luncheon meat type A* and the *beef and gravy*, which contribute 6.2 g of salt between them. The salt contributed by the soup and gravy bases has been considerably reduced to a more acceptable 10 to 16%. No items have been cited (Table 6) as failing salt specifications, but, as discussed earlier, some items could be interpreted as failing the salt specification. Na exceeds the upper limit recommended by the NH & MRC (1987), however as users may have need to acclimatise to warmer conditions there would be need for salt in excess of the recommended amount for normal civilian occupations. Approximately a third of the available Na (2.84 g) can be taken at the discretion of the user as salt. Thus, 4.4 to 6.6 g Na are incorporated in the various food items, around twice the amount recommended by the NH & MRC (Table 1).

The concentration of the vitamins riboflavin and niacin in the components of this ration (Table 10) compared with the requirement (Table 1) show no cause for concern. Total riboflavin content exceeds the requirement for a grade 3 level of activity and far exceeds the requirement to process the energy available in the ration. Total niacin content is of the order of the requirement for a grade 2 level of activity and exceed the requirement to process the available energy in all menus except the A menu. Further niacin can be derived from protein available in the ration.

The initial samples of the 1987 CRIM have a much lower total thiamine content than the samples stored in warehouses for one year (Table 10). This suggests that either the components provided in the initial samples were from an older procurement than the stored samples, or the initial samples received very poor storage treatment from the time of packaging, during transport to Tasmania to receipt at the laboratory. The initial samples were received late December 87 that were due for delivery August 87. While awaiting delivery these samples may have been held in very poor conditions in Sydney or Melbourne. Some items were found to have different batch numbers, which shows that some of the previous procurement components have been stored for an additional year before being packaged into rations. Inspection of the individual results shows that some items (e.g. *coffee* and *chocolate*), which should have been fortified, had no detectable thiamine. Most of the thiamine in the ration was found in items with no requirement for fortification. If these initial samples (Table 10) are representative of the ration as received by the users, then there is considerable cause for concern as three menus contained less than the requirement of thiamine (Table 1). If the ration stored for one year is more representative then there is no cause for concern as the content exceeds twice the requirement.

The total ascorbic acid content in the ration stored for one year averages 73% of the initial content (Table 10). Even at this stage it averages over three times the requirement (Table 1). The rations which have the highest content of ascorbic acid after one year are those with *fruit candy* instead of *sweet and sour candy*. *Sweet and sour candy* is not fortified with ascorbic acid, while *fruit candy* has been fortified. *Fruit candy*, as discussed above, has been shown to stabilise ascorbic acid for up to four years. It contains sufficient ascorbic acid to meet the daily recommended intake. It is recommended that *sweet and sour candy* be fortified to the same level as *fruit candy*. Another major contributor to total ascorbic acid are the fruit drink powders, however, Forbes-Ewan and Waters (1986) showed that the old formulation was discarded by many users. There is no evidence to show that the new formulation has been accepted by the users, who may still discard this item. The remaining items with significant concentrations of ascorbic acid have been

shown to be poor carriers and are unlikely to retain sufficient to remain significant contributors. Thus, there is need to identify additional components suitable for ascorbic acid fortification.

The contents of P, Ca, Mg, Fe and Zn (Table 11) exceed the requirement (Table 1). The ratios of Ca to P ranges from 1:0.78 to 1:1.5, which are close to the recommended 1:1 ratio (Whitney and Hamilton, 1984). The average Mg content is 314 mg/ration which is close to that recommended (Table 1). The total Ca and Mg levels are similar to the totals found in the previous CR1M (James, Hancock & Tattersall, 1985). Fe and Zn although in excess, represent no known toxic hazard as the totals are well below daily intakes known to lead to toxic symptoms (Roeser, 1986; Dreosti, 1982).

The total Cu contents (Table 11) are deficient with respect to the requirement (Table 1). Only menu B is close as it barely meets the minimum recommended daily intake. The total Cu found was marginally less than the total found in the previous CR1M (James *et al*., 1985). There are also similar deficiencies in some of the IMCR menus (James *et al*., 1988). The CR1M ration is energy deficient at the levels of activity required of Australian servicemen and this deficiency of Cu could be regarded as part of this general deficiency. However, the civilian population is expected to attain the required intake of copper with a much lower energy consumption. Therefore, the CR1M ration is regarded as Cu deficient.

Cd concentrations in *freeze dried rice*, *cereal biscuits*, *bacon & beans*, *fruit candy*, *survival biscuits* and *tea* marginally exceed the limits set by the NH & MRC (1990). Most components had undetectable concentrations of Cd. The total for the various menus ranges from less than 10 µg to 40 µg, which is considerably less than the minimum daily (200 µg) intake known to cause urinary toxicity symptoms (Spivey Fox, 1988).

Pb concentration in *orange beverage powder* marginally exceeds the limit set by the NH & MRC (1990), but this will be considerably diluted when used. Most components had no detectable Pb. The total for the various menus ranges from 0.2 mg to 0.4 mg. Concern has been expressed that even very low concentrations of Pb may have adverse effects on the nervous system (Spivey Fox, 1988). However, except for cases of contaminated soil, food is not regarded as the major risk of Pb toxicity, rather the major risk arises from airborne dust and fumes. Since almost all the concentrations were within the NH & MRC guidelines (1990), these totals are considered safe.

When using these rations it is assumed that the user commences use in a good nutritional state. The user's body reserves of energy, ascorbic acid, thiamine and copper will be used to meet any deficit between intake from the CR1M and expenditure undertaking operational activities. Depending on the initial nutritional status and the actual level of activity, the user can be expected to perform well for one to three weeks. Toward the end of this period some loss of performance can be expected.

4. *Conclusions*

Ascorbic acid was found to be relatively stable in *fruit candy*, new formulation fruit drink powders, *beef noodle* and *pea & ham soup* powders, but less stable in *chicken noodle* and *tomato soup* powders. No other variables have been identified to

explain these differences. It could be due to the differences in the food matrix, however, it is more likely to be due to ineffective sealing of packaging.

Ascorbic acid was found to be unstable in *chocolate, instant coffee,* IMCR main meal components and *unsweetened condensed milk.* Encapsulation was found to improve the ascorbic acid stability marginally in *chocolate* only if added after refining. Ascorbic acid stability was found to be very temperature dependent with a decline in stability developing at around 20°C. This effect was found to be dramatic above 30°C and leads to concern that ascorbic acid concentrations would decline rapidly during summer in normal warehouse conditions.

There is need to find more carriers suitable for fortifying with ascorbic acid. The most successful carriers for ascorbic acid would be confections similar to *fruit candy,* ie. 'CHEERS'; the new fruit drink formulations used in the revised CR1M have also shown promise, but would depend on a good packaging seal.

Thiamine was found to be unstable in *instant coffee,* IMCR main meal components, soup powders, and *chocolate.* The results on cereal products stored for one year in the revised CR1M suggest that thiamine is relatively stable in cereal products. This would suggest that thiamine could be relatively stable in some freeze-dried components, as the protection is largely derived from the low moisture conditions preventing degradation reactions proceeding. The results suggest that a successful strategy would be to fortify to a level sufficient to ensure adequate thiamine remains to meet nutritional needs after normal storage.

If the remaining products, such as wet canned meals, are to be used as carriers for ascorbic acid and thiamine fortification, then they must be stored below 20°C. This cannot be achieved in mainland warehouses during summer without providing better facilities. An alternative would be to store rations in warehouses normally at temperatures below 20°C, such as the Hobart and Puckapunyal warehouses. These products could only be stored in tropical warehouses for a few weeks, and it would be desirable for cool storage to be provided in such warehouses. If better facilities cannot be provided then the fortification of these products should be increased to compensate for the losses through degradation during storage.

Riboflavin was found, as expected, to be relatively stable in IMCR main meal components and soup powders, and should meet nutritional needs without fortification.

Niacin was found, as expected, to have adequate stability in IMCR main meal components and soup powders. There is adequate niacin available in rations to meet nutritional needs without fortification.

It is almost impossible to police a salt specification while it is stated in terms of added salt. At least two IMCR meals are exceeding the planned salt content of 0.76%. This specification should be set in terms of a maximum including natural levels, that is, total salt.

AGAL methods of treating some samples are not adhering to the statistical design of the sampling program. Their treatment of samples must be adjusted so that the complete set of data points is available. Should legal action be desired, this sampling treatment could lead to such action being unsuccessful.

The nutrient levels in IMCR are generally adequate for their designed purpose. However, the storage stability of thiamine and ascorbic acid in them is unsatisfactory. As the ration is only designed for intermittent use, there is unlikely to be any problem. However, if the user is also being fed by catering systems with long holding times, as may occur in some messes, or with hot box supply of "fresh food" in the field, then over a period of a few weeks some users could develop

deficiency problems. A particular concern would be heavy alcohol drinkers, who tend to be at risk in normal civilian conditions.

The nutrient levels in the revised CR1M are deficient for use by Australian servicemen undertaking normal military activities. The total amount of energy derived from the nutrients is not even adequate to meet the minimum energy expenditure found in practice. Thus, there is need to increase the energy content of the ration, preferably to around 15,000 kJ, which would meet the minimum requirements.

The vitamins remaining after one year warehouse storage does suggest that sufficient should be available when consumed to meet the users needs. Ensuring that fortification specifications are met would assure sufficient is available at consumption.

All the efforts to design, prepare and issue well designed, nutritionally balanced rations will be defeated if users discard items. An educational program directed at users, caterers, their officers and medical officers to make them aware of the ration design and functions of the various components should be justified on efficiency and effectiveness criteria.

5. *Recommendations*

1. ADFFS (DPI, 1984/8) must be observed and enforced.

2. ADFFS (DPI, 1984/8) include a requirement to use the head space correcting method of gauge pressure determination.

3. *Fruit candy, sweet and sour candy,* and any other similar candies require fortification with ascorbic acid.

4. Fortification of cereal products with thiamine be considered.

5. The storage stability of thiamine and ascorbic acid be investigated in freeze-dried products.

6. The energy content of the CR1M be raised to 15,000 kJ.

7. The fat specification for selected components, such as main meal items, include a lower as well as an upper limit.

8. An educational program be prepared and used to make users, caterers, their officers and medical officers aware of the functions of the various ration pack components.

9. Action be taken to ensure that quality assurance sampling and analysis adheres to ADFFS (DPI, 1984/8).

10. ADFFS (DPI, 1984/8) specifications in terms of added salt be rewritten in terms of total salt in the finished product.

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ABSTRACT

The results of studies of the storage stability of ascorbic acid, thiamine, riboflavin and niacin in fortified ration pack components are reported. Fortification of selected ration components with ascorbic acid and thiamine was found to be necessary but fortification with riboflavin and niacin was found to be unnecessary. Additional carriers for fortification with ascorbic acid and thiamine need to be identified. Conditions in most Australian Defence Force warehouses lead to rapid depletion of ascorbic acid and thiamine. The results of analysis of 1986 and 1987 procurement of rations are reported and discussed, including a nutritional assessment of the Individual Meal Combat Ration (IMCR) and the revised Combat Ration One Man (CR1M). Some nutrient levels in the IMCR were found to be inadequate. The energy level of the CR1M was found to be deficient in copper. Adequate levels of ascrobic acid and thiamine in CR1M at the time of consumption are dependent on adequate fortification. The assessment of compliance with salt specifications stated in terms of added salt was found to be almost impossible. Some deficiencies in the rations are related to failure of some components to meet specifications.

Laboratory Evaluation of Australian Ration Packs

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(MRL-TR-92-30)

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